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STRATIGRAPHIC VALUE OF DISCOASTERS AND SOME OTHER MICROFOSSILS RELATED TO RECENT COCCOLITHOPHORES

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ABSTRACT.—Much scientific work has been done on Recent Coccolithophoridae and some fossil forms have been described, but little attention has been given to their value in biostratigraphy. Some largely extinct forms which may be closely related to these minute algae have been known under the generic term *Discoaster*. The systematic position of the discoasters is uncertain; originally Ehrenberg regarded them as inorganic "Crystalldrusen," but it is now evident that they are the skeletal remains of nannoplanktonic organisms. Despite the little taxonomic work done and the difficulties involved, present data indicate the probability that the discoasters, especially, may aid in world-wide correlation of certain Tertiary time horizons.

The very small (about 10 microns) calcareous remains of these organisms are common in some late Mesozoic and Tertiary rocks, particularly in those of open-sea deposition, and constitute the main bulk of some chalky sediments. Distinctive forms characteristic of certain parts of the Tertiary are found on both sides of the Pacific and Atlantic oceans, including the Caribbean and Mediterranean regions, and elsewhere. Some of these are described and some data presented on their stratigraphic distribution.

INTRODUCTION

THIS investigation was initiated during the microscopic examination of the fine constituents of bottom sediments from the Pacific Ocean. It was noted that the assemblages of coccoliths and other minute calcareous skeletal remains in certain cores which penetrated Tertiary strata were strikingly different from those of the Recent sediments of the region. Examination of available Tertiary calcareous rocks of reasonably well-established age revealed many equally abundant and distinctive assemblages. Nearly three hundred Tertiary and some Cretaceous samples from various parts of the world have been examined thus far, and the wide geographic distribution of some of the forms is impressive.

This report must, however, be considered as preliminary, as only some of the more distinctive forms have been studied, and adequate checking of their occurrence is far from complete. Nevertheless, the data now available indicate the real value of these microfossils in biostratigraphy and seem adequate to show tentative age ranges of certain distinctive forms, which will probably not be very greatly modified with additional data.

[1] Contributions from the Scripps Institution of Oceanography, New Series, No. 717. This work represents results of research supported, in part, by the Office of Naval Research.

The many samples have been obtained from so many sources that acknowledgments can hardly be given here. Many foreign laboratories of oil companies, universities, and government agencies have kindly supplied material along with the best available data on their age.

The coccolithophores, which form an important element of the oceanic plankton at the present time, have been intensively studied. These biflagellate protists occur in vast numbers in the near-surface waters of the open oceans, and a few species are known from brackish and even fresh waters. The complete skeletal remains usually have a spherical or roughly spheroidal form, but these coccospheres are so fragile that they are much less common in bottom sediments than the disaggregated tiny plates called coccoliths. Classification of the living forms is based largely on the calcareous hard parts.

Many papers are available on the Recent coccolithophores. This paper, therefore, is concerned largely with some related forms—particularly with those included under the "form genus" name *Discoaster*. The organisms responsible for the formation of skeletal remains classed as discoasters are not known to be living at present and there is therefore no certainty of their close relationship to the typical coccolithophores. Indeed some doubt exists that discoasters represent the remains of a single-celled organism—plant or animal—as indicated in the subsequent discussion of taxonomy.

The fossil forms, especially of the coccoliths, constitute a major part of some chalky formations of the Cretaceous and Tertiary, and are common in many calcareous shales. Few, or none, are found, however, in other fossiliferous marine strata that seem to represent less open sea conditions. Thus Tertiary sediments containing Globigerinas or other pelagic Foraminifera are apt to contain many coccoliths as well as other planktonic forms such as *Discoaster*.

Occurrence of such minute calcareous forms is limited also by the degree of lithification and recrystallization of the rocks. Any such forms are apt to have been obliterated in hard limestones. Even in fine-grained limestones, where recrystallization is less advanced, the extraction and identification of any remaining forms is difficult.

Type specimens will be deposited in the U. S. National Museum, Washington, D. C.

PREVIOUS WORK

Ehrenberg (1836) first mentioned the small ovoid bodies occurring in the chalk, but considered these coccoliths to be of inorganic origin. Huxley (1858) noted their presence in Recent oceanic sediments and applied the name "coccolith." Sorby (1861) showed that coccoliths were derived from small hollow spheres, and that those of the chalk were not inorganic but similar to Recent coccoliths; he evidently examined the Recent forms and came to this conclusion without knowledge of Professor Huxley's work.

The more intensive work, including systematics, came much later, beginning with Lohmann (1902), followed by Schiller (1930), Kamptner (1941), and others.

Ehrenberg was likewise the first to note the small stellate bodies now known as discoasters, and several were figured in his great volume "Mikrogeologie" (1854, pls. 24 and 25), though he considered them inorganic calcareous "Crystalldrusen." He had earlier (1844) described some rather similar forms under the generic name *Actiniscus*, but evidently recognized their opaline composition and included these along with diatoms in his Polygastrica.

Jukes-Brown and Harrison (1892, p. 178) figured several such calcareous "stellate bodies" from the Oceanic formation of Barbados. The first systematic work was by Tan Sin Hok (1927), who applied the name "Discoaster" to the group and briefly described, with figures, several species and varieties from the late Tertiary of Indonesia. A few forms were described by Sujkowski (1930) from Poland, and by Bersier (1939) from the Molasse of the northern Alps. It seems probable that Bersier's specimens were reworked from older strata because of the rarity of specimens, their similarity to earlier Tertiary forms and their occurrence in apparently non-marine Molasse. Parejas (1934) described some specimens from the Upper Cretaceous which resemble *Discoaster* in form and size. These had a siliceous composition, however, and were therefore included in Ehrenberg's genus *Actiniscus*. Colom and Gamundi (1951) figured several

forms of *Discoaster* from the middle Tertiary of Majorca, and identified them under names applied by earlier workers. Most of the work since 1934 has been by Deflandre, and is summarized with his views on their systematic arrangement in the Traité de Paléontologie (1952a) and more completely in the Traité de Zoologie (1952b).

METHOD OF STUDY

Vast numbers of coccoliths, discoasters, and other related forms occur in the fine-grained calcareous sediments of the present ocean bottom and in many chalky rocks of the Tertiary and Cretaceous. A few cubic millimeters is thus an adequate amount of many such rocks. Boiling of the sample will usually disaggregate sufficient fine material that can be decanted onto a microscope slide and dried. Canada balsam or other mounting medium and a cover glass complete this simple preparation. Moving the cover glass over the viscous Canada balsam permits varied orientations of the minute specimens, and a permanent mount may be prepared subsequently by slow cooking of the preparation.

Microscopic examination at magnifications of 400 to 500 diameters seems adequate for discernment of the distinctive features of the discoasters and some coccoliths, though higher magnification with an oil immersion lens is helpful, and in some cases necessary. A phase-contrast microscope which permits continuous variation through different conditions of illumination is very useful, as certain details appear best under different phase-contrast conditions between the dark-field and normal illumination. This is particularly important because of confusing effects commonly caused by much refraction in normal illumination. A universal stage for various orientations would be valuable, if adequate magnification were possible with this accessory.

Discrimination of important characters of the coccoliths, especially of those less than 5 microns in diameter, is more difficult, requiring high magnification and preferably supplemented with observations under polarized light. Kamptner (1952) has found remarkable and distinctive characters in the arrangement of the calcite micelles forming the structure of different types of coccolith. The orientations of the minute micelles of the fibrous structure are determinable, even under high magnification, only because of the high birefringence of calcite under crossed nicols. The electron microscope is also proving valuable to the specialists working on the coccoliths. Such elaborate methods of study are important to taxonomy, but the usefulness of such discrimination among the smaller coccoliths is limited in stratigraphic work, because the determination of their distribution in space and time requires the examination of such a great number of specimens from many samples. Only two coccoliths of unusually large size are preliminary described in this paper.

Photography is, unfortunately, not very satisfactory for reproducing these small objects, as depth of focus is insufficient at the required magnifications. Drawings are required to reproduce features which can be discerned only by varying the focus and the phase-contrast lighting.

MATERIAL STUDIED

In addition to the many Recent and some Tertiary samples from the ocean bottom, nearly 300 surface samples from many parts of the world have been examined to date. None of these samples has been thoroughly studied, however, and only some of the more easily differentiated forms, including most of the distinctive discoasters, are considered here. Most of the samples selected are from strata of reasonably well established age.

Relatively few samples of Cretaceous age have been examined, as forms identifiable as *Discoaster* are rarely if ever present, though coccoliths are abundant and of great variety. Very few data are now available on Pliocene occurrences, as samples from an open-sea environment with considerable pelagic elements seem strangely uncommon in identifiable Pliocene strata. Many good samples from Miocene strata are available from countries of the Mediterranean, Caribbean, and Pacific borders. Available samples from Oligocene strata are largely limited to the Caribbean region. The largest number of samples are from different parts of the Eocene from many parts of the world, and these contain the most abundant and dis-

tinctive assemblages. Fewer samples, but from widely separated parts of the earth, are available from the Paleocene.

BIOSTRATIGRAPHIC CONSIDERATIONS

The available data on their distribution in space and time indicate that, among these small planktonic organisms, at least the discoasters can be used in attempts to correlate strata—and they are perhaps more useful for interregional correlation than for the correlation of local units of short duration. Because of the relatively limited number of distinctive forms of *Discoaster*, it is doubtful that these alone could be used for local subdivision of minor stratigraphic units in the same manner as are the Foraminifera. Assemblages which include many forms having different but in part overlapping time-ranges are obviously more reliable age-indicators than individual "guide-fossils," but *Discoaster lodoensis* is an example of a species which may prove useful as a guide-fossil. This species has been found in the Capay (lower Eocene) of California, in the Ramdat (lower Eocene) of Trinidad, in the basal shale of the Plaisance limestone (middle Eocene) of Haiti, and in strata classed as lower Lutetian (middle Eocene) of Donzacq, France. It has not yet been found in strata of earlier or later age, and thus seems to be widely distributed in the lower Eocene and the lower part of the middle Eocene. Only their value in age assignments can be considered at this time, as the following few remarks indicate the little present knowledge bearing on ecologic and other aspects in stratigraphy.

These small planktonic organisms are presumably subject to fewer or less complex ecologic controls than benthonic organisms. Only a few forms, and these of the typical coccolithophores, are known to exist in fresh water, and some others in brackish water, but an abundance of varied forms is characteristic only of the open oceans. At least those known to be algae would be largely limited to near-surface waters, and so their distribution is probably affected by the near-surface temperatures. Lohmann (1902, pl. 6) shows the coccolithophores at one station in the Mediterranean to be largely limited to depths above 150 meters, and the great abundance to depths of 25 to 75 meters. Bernard (1948) reported *Coccolithus fragilis* Lohmann as abundant down to depths of 1000 meters in the Mediterranean, but apparently he did not determine that the cells were actually alive at such depths. Moreover, the compensation depth for general phytoplankton is 100–150 meters in the very clear water of the Sargasso Sea (Riley, 1939, p. 153), and it is likely that the water of the western Mediterranean is not so clear and that therefore there would not be enough light for the growth of coccolithophores even at 150 meters at Bernard's localities. Though some coccolithophores are known from Arctic waters, most of them occur in temperate or tropical waters—especially such forms as *Rhabdosphaera*. The abundance, large size and variety of forms in the Eocene may reflect the generally warmer oceans of that time.

Nothing is known yet about ecologic controls which affected such largely extinct groups as that including *Discoaster*. The former occurrence of species over widely separated parts of the earth suggests, at least, that prohibitive controls were not common, though data from high latitudes are not available.

Records of coccoliths before Jurassic time seem doubtful, and only beginning with the Cretaceous are vast numbers found in the rocks. Because of their extreme delicacy and the consequent tendency for corrosion or secondary growth during lithification to limestones, it seems possible that they developed much earlier than Jurassic time, but have been largely obliterated in earlier strata along with the conversion of any chalks to fine-grained limestones.

Forms referred to *Discoaster* have been reported from the Cretaceous, but we have been unable to substantiate such pre-Tertiary occurrences and have not found them in the considerable number of samples examined. The only possible exceptions are in samples such as one from the Velasco shale of Mexico, which is considered either Paleocene or uppermost Cretaceous (Danian). Ehrenberg (1854, pls. 24 and 25) figured specimens of what appears to be *Discoaster barbadiensis* from "Kreidefelsen" of Egypt and Antilebanon. Other constituents of these samples, including the Forami-

nifera, are quite different, however, from those of his samples of "Kreidefelsen" which are known to be Cretaceous chalk, and none of the latter show forms resembling *Discoaster* though coccoliths are abundant. Early Tertiary chalk and marl are now known to occur also at the poorly defined locality of Thebes in Egypt and in Antilebanon, and it seems probable that these "Kreidefelsen" samples were post-Cretaceous. Certain forms described by Sujkowski (1930) apparently came from the Cretaceous of Poland, but those resembling Tertiary discoasters were only one-fifth the size of known discoasters, and such forms are as yet unknown elsewhere.

The latest occurrence of *Discoaster* is likewise open to some doubt. A plankton catch from the Mediterranean contained a single specimen that was named *D. planktonicus* by J. Lecal (Archives de Zoologie, 1952). This specimen of spherical form (about 30 microns in diameter) had many stellate objects on the surface but it was stated that these elements seemed to be of "amorphous" material under polarized light rather than calcite. No examples, with the possible exception of rare *D.* aff. *D. aster* (see p. 400), have been observed by us in the many Recent samples, except where there was other evidence indicating reworking or where such derivation could be expected. A supposed Recent occurrence was recorded from a South Atlantic bottom sample, *Challenger* Sample No. 338, first figured in the *Challenger* volume on Deep Sea Deposits (Murray and Renard, 1891, pl. 11). One of these figures was taken by Tan Sin Hok as representing the type of his *D. molengraaffi*. Dr. Ovey of the British Museum kindly sent us part of this original sample, and several different forms identical with those of the Miocene were found, but they were very rare among the abundant coccoliths and other skeletal remains of Recent aspect. Because of the irregular bottom topography and proximity to the mid-Atlantic Ridge, it seems probable that here as in some areas with substantiating evidence, the specimens of *Discoaster* were derived from Tertiary deposits which locally slumped, along with the thin cover of later deposits, from a steep slope of the sea-floor. The minute size of these fossils permits them to be transported much farther than Foraminifera, as the latter are many thousand times greater in bulk.

Only some of the more common and widely distributed forms of *Discoaster* are described in this paper, and some data on their distribution in the Tertiary are given. Perhaps an equal number of distinctive forms have been observed, but remain to be described after compilation of additional data on their variations and distribution. It is evident, however, that the number of "species" of *Discoaster* is less than that of typical coccolithophores.

The wide geographic distribution of many species is evident. Some general data on their occurrence in time are indicated with their descriptions, but no attempt at a precise age range of the described forms is justified at present. *Discoaster barbadiensis* is indicated as common in samples throughout the Eocene, but we have not attempted to discriminate closely within this "form species." It seems to terminate rather abruptly, as it has not been observed in samples classed as lower Oligocene, though most such samples are available only from the region of middle America. An interesting example of its upper limit of range is found in a sequence of 38 samples of the Oceanic formation from Bath, Barbados. *D. barbadiensis* is very common in the lower 30 samples and absent in the upper eight samples. The upper part of the Oceanic is considered Oligocene by Senn (1940) and others who have studied the foraminiferal faunas. The change in the radiolarian faunas which the junior author considers to indicate an Eocene-Oligocene boundary is found between two samples separated by only a few meters of strata. Surprisingly, the change in the discoaster assemblage occurs between these same samples—with the dropping out of the common *D. barbadiensis*. Perhaps this reflects some change in the surface waters, as a considerable hiatus or other discontinuity would not be expected in the rather uniform Oceanic formation of relatively deep water deposition.

Most strata of Oligocene age seem to have a much less varied assemblage of discoasters and coccoliths than those of the Eocene, but a number of new forms appear in the Miocene. The phylogenetic relationships

of the distinctive Miocene forms are obscure. The approximation to synchrony of their appearance within the middle Tertiary of many parts of the world presents an interesting problem. They occur in the few samples examined from the middle and upper Miocene of the Mediterranean region, but not in samples from the Aquitanian and Burdigalian of the Aquitaine basin. The few available samples which can reasonably be considered as typical Burdigalian do not contain a good discoaster assemblage, but the one species present is one common in the Oligocene. In the Caribbean region, a corresponding change from the forms characteristic of the Oligocene and lower Miocene (Burdigalian) of Europe to the distinctive ones of the upper Miocene of Europe is very striking. In the many samples from the Caribbean region, however, the change occurs between strata classed as middle Oligocene and those generally classed as upper Oligocene. This same change occurs in some samples from Indonesia which had been assigned to the upper part of the Tertiary east of that region.

Much additional study of the discoasters, coccoliths, and related forms is needed before any such biostratigraphic relations can be established, and any time-stratigraphic significance must be evaluated with reference to other paleontologic evidence. Both theoretical and observational considerations suggest, however, that these planktonic organisms may be more widely and quickly distributed over the oceans than most other organisms.

These small fossils are commonly only 3 to 15 microns in diameter and thus near the size limits between clay and fine silt particles. Erosion and transportation may thus distribute them widely and produce a serious problem of reworked specimens. Although reworking of microfossils (e.g. Foraminifera and Radiolaria) is not uncommon, it is usually not justifiable to explain unexpected stratigraphic occurrences as being due to reworking, unless other evidence supports such an interpretation. Supplementary evidence of the reworking of coccoliths and discoasters is common enough, however, to indicate that these microfossils are reworked more commonly than are many other fossils.

One good example of reworking is evident in the core MP 27 from the Mid-Pacific samples described by Hamilton (1953). Slumping from a nearby guyot produced a sediment with a mixed assemblage of Recent, middle Tertiary, Paleocene and Cretaceous Foraminifera. The fine fraction of this sediment contains also an anomalous mixture of discoasters. Characteristic species of Foraminifera were selected and crushed individually, and the assemblages of discoasters and coccoliths from within the chambers were correspondingly distinct. The Paleocene form, *Discoaster multiradiatus*, was common from within chambers of *Globorotalia velascoensis*, middle Tertiary forms such as *D. brouweri* and *D. challengeri* were common in specimens of *Globigerina altispira*, and distinctive Cretaceous coccoliths without discoasters were found in specimens of *Globotruncana arca*.

An Oligocene marl from Mariel, Cuba, offers a similar example, where a considerable number of discoasters normally occurring in the Eocene are found together with the more numerous Oligocene forms. Rare specimens of such characteristic Eocene Foraminifera as *Hantkenina alabamensis* and *Globorotalia cerro-azulensis* were found among the abundant Oligocene Foraminifera. Crushing of the thoroughly washed Eocene specimens showed Eocene discoasters, and quite a different assemblage was found in crushed specimens of the common Oligocene Foraminifera.

Because of their very small size, some reworked specimens may be expected rather commonly even though Foraminifera and larger fossils were not transported equally far from the source. Several samples from the Miocene of Haiti thus show some specimens of various Eocene discoasters and coccoliths, though reworked Eocene Foraminifera were not found. A similar derivation from the Eocene is believed to explain the recorded occurrence by Colom and Gamundi (1951) of *D. barbadiensis* in the Aquitanian-Burdigalian strata of Majorca. Samples kindly supplied by Colom show this form to be uncommon among the abundant middle Tertiary assemblage. It seems probable that such widespread and common forms as *D. barbadiensis* will be found reworked in later sediments so commonly

that the actual life span may appear very doubtful. This form, so abundant in the Eocene, seems to be entirely absent, however, in the post-Eocene strata of many places where there is no evidence of other reworked elements. The available data thus indicate that *D. barbadiensis* lived only during the Eocene, and sporadic occurrences in strata of later age should be considered carefully for other evidence of derivation from reworking of Eocene material. The evidence of reworking is thus found commonly enough to require serious consideration in biostratigraphic interpretations from all of these exceptionally small fossils.

TAXONOMY

The systematic classification of fossil coccoliths, discoasters, and similar forms is beset with even more difficulties than are associated with that of most other groups of fossils. Apart from the lack of knowledge of the soft parts of some of the organisms, the problem is complicated by the dissociation of the skeletons into isolated skeletal parts, as with most coccoliths and all discoasters. In the case of the coccoliths, the forms which are still living give some indication of the methods to be applied in the classification of the fossil forms, but *Discoaster* apparently has few or no close relatives living, and although *Braarudosphaera*, *Thoracosphaera*, and *Ceratolithus* are evidently now living in the oceans, we have no knowledge of their soft parts.

A review and revision of the classification of all of these organisms and their isolated skeletal parts was presented by Deflandre (1952b). He grouped all of the forms dealt with in this paper into the class Coccolithophoridés of the Flagellata, although pointing out that there is little real evidence to justify the inclusion of *Braarudosphaera*, *Thoracosphaera*, and the discoasters. He divided this class into two orders, on the basis of the microstructure of the calcite of the skeletal parts: the Heliolithae (including all the coccoliths; tremaliths, rhabdoliths and lopadoliths), the skeletal parts of which have a radiating-fibrous structure, and the Ortholithae (including *Thoracosphaera*, *Braarudosphaera* and the discoasters), in which the skeletons or larger parts thereof have the optical properties of single crystals. Subdivision of these two orders was based on general morphological characters.

The skeletal structures of Deflandre's group Heliolithae include the common forms of coccoliths (simple or double, circular or elliptical calcareous plates often bearing some type of ornamentation), and other distinctive forms of coccoliths such as rhabdoliths (small plates surmounted by long hollow rods of various types) and lopadoliths (varying in shape from short, barrel-like to long and tubular). In some living members of this group, two different types of these skeletal elements are present on the same individual.

As this order (Heliolithae) contains many living forms, it has been divided by a classification based in part on the structure of the entire skeleton. Because of the dimorphism of the skeletal elements of some members of this group, the fossil remains, occurring usually as isolated parts, cannot be classified according to such a system, and therefore Deflandre and Deflandre-Rigaud have proposed an artificial classification of the isolated skeletal parts into manipules and centuri instead of genera and species, along the lines suggested by Croneis (1938).

Only two unusually large and distinctive coccoliths are described in the present paper. The form which we describe as *Coccolithus grandis* has been figured as a complete coccosphere by Deflandre (1952b) and thus it can be referred with some certainty to the genus *Coccolithus*. The other is assigned only to a manipule (*Tremalithus*), because we do not know the nature of the complete skeleton.

COCCOLITHUS GRANDIS Bramlette and Riedel, n. sp.

Plate 38, figures 1a, b

"Coccolith," JUKES-BROWNE and HARRISON, Quart. Jour. Geol. Soc., vol. 48, p. 178, fig. 7, 1892.

Coccolithus cretaceus Archangelsky of DEFLANDRE, Traité de Zoologie (ed. P.-P. Grassé), vol. 1, fasc. 1, p. 463, fig. 360 D, 1952.

Placoliths unusually large, consisting of two curved plates, of which the lower is nearly as large as the upper. The two plates are so closely appressed that it is impossible to see the connecting tube in side view. A large part of the central area of the placolith is occupied by an X-shaped cross, which

can be observed on both surfaces of the placolith as it bridges the large central opening. The calcite of this cross acts optically as a single crystal, in contrast to the fibrous structure that is usual in coccoliths. Very fine striae are observable on the border of both plates. Major diameter usually 18–23 microns.

This species resembles the older *C. cretaceous* Archangelsky, which is consistently much smaller.

Type locality.—Scripps Mid-Pac Core No. 25 E-1 (Lat. 19° 40′ N., Long. 168° 32′ W., depth 931 fm.).

Other occurrences.—Lower part of Oceanic formation (Eocene), Mt. Hillaby, Barbados; lower Lutetian, Donzacq (Landes); Lodo formation (Capay stage, lower Eocene); Lodo Gulch, Fresno County, California; also at many other widely scattered Eocene localities.

Discussion.—This form is common in the Eocene, particularly in the middle and lower Eocene. Its upper limit is uncertain, but it is much less common than *Tremalithus eopelagicus* in the upper Eocene.

TREMALITHUS EOPELAGICUS Bramlette and Riedel, n. cent.
Plate 38, figures 2a, b

"Coccolith," JUKES-BROWNE and HARRISON, Quart. Jour. Geol. Soc., vol. 48, p. 178, fig. 8, 1892.

Placolith unusually large, elliptical, consisting of two curved plates of which the lower is slightly smaller than the upper. The plates are rather closely appressed, and therefore the thick-walled connecting tube is visible in side view only through the thin, curved edges of the plates. In surface view the plates show an elongated central slot and, peripherally, fine curved radiating striae. Major diameter usually 16-20 microns.

This placolith is larger than any other described form, except for the distinctive *Coccolithus grandis*, with which there are otherwise no similarities. Consistently smaller forms rather similar to *T. eopelagicus* are found in middle Tertiary and later strata.

Type locality.—Middle of the exposed Oceanic formation at Bath, Barbados.

Other occurrences.—This form is very common in the middle Eocene through lower Oligocene from many parts of the world.

No attempt is made in this paper to discuss the Tertiary rhabdoliths, lopadoliths and other types of coccoliths. However, when more work is done, they may prove useful stratigraphically. Among other rhabdoliths one large form (pl. 38, fig. 3) has been noted commonly in early Tertiary strata: this form may be closely related to *Rhabdolithus perlongus* Deflandre (1952b, fig. 362 I, from the Lutetian, figured without description or dimensions).

Some of the early Tertiary rhabdoliths, such as that figured (pl. 38, fig. 3), do not show the parallel extinction under crossed nicols which Kamptner (1952) found in the

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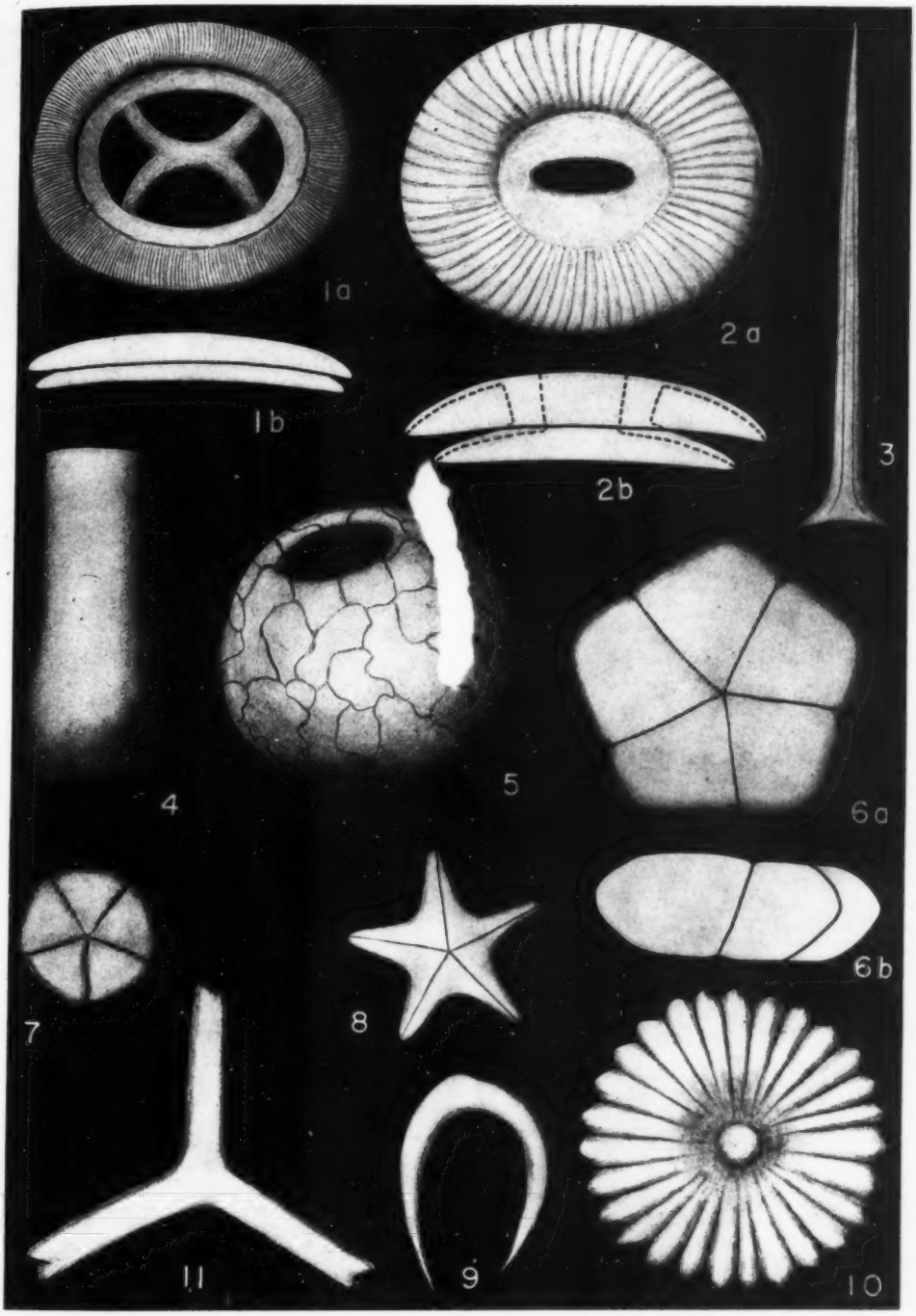
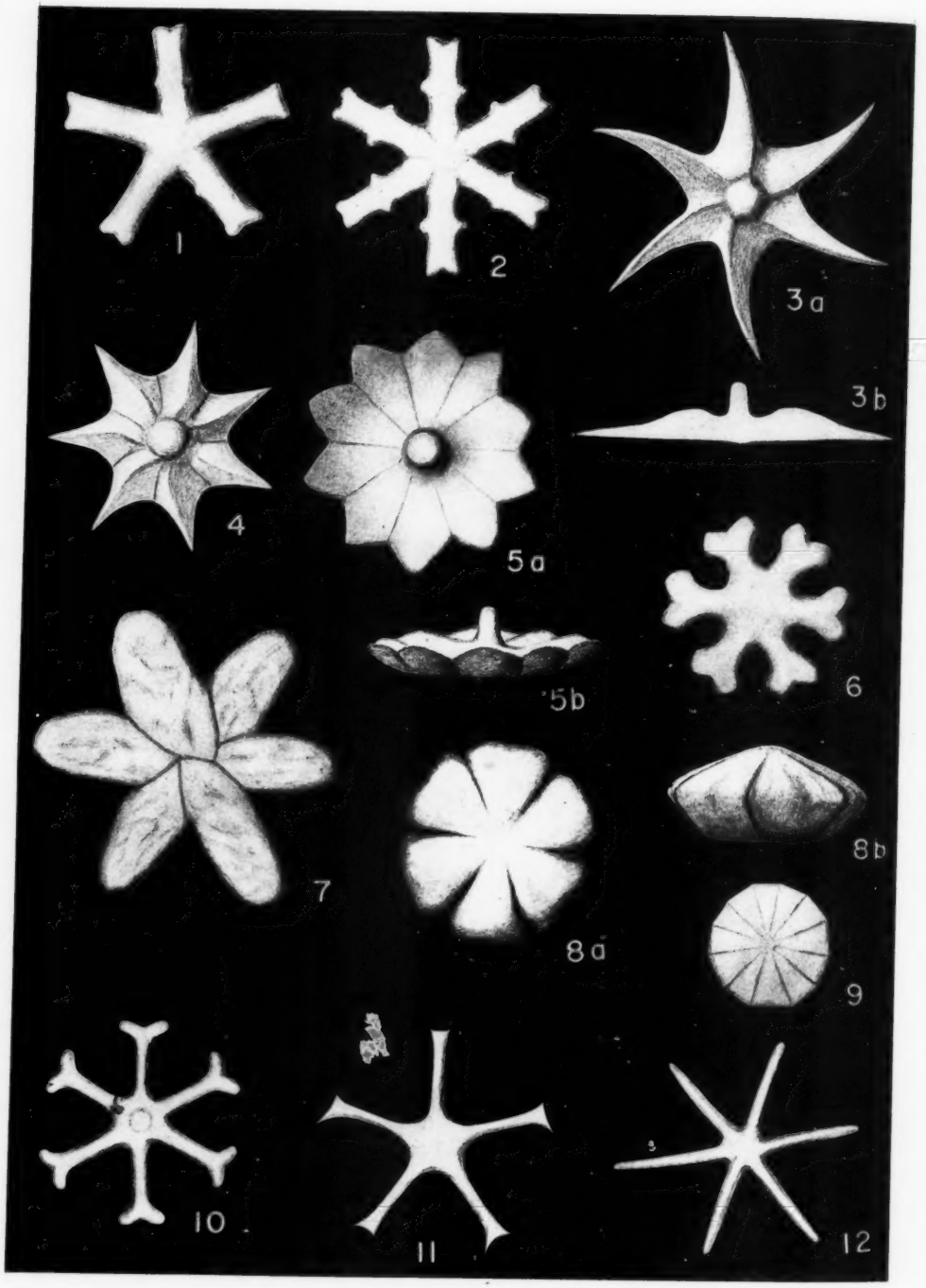
EXPLANATION OF PLATE 38

All illustrations ×2500.

FIGS. *1a, b—Coccolithus grandis*, n. sp. *1a*, vertical view of holotype; *1b*, sketch of slightly oblique lateral view. (p. 391)
2a, b—Tremalithus eopelagicus, n. cent. *2a*, vertical view of holotype; *2b*, sketch of lateral view showing an optical section. (p. 392)
3—Large rhabdolith from the upper Eocene near Isney, Alabama (same as type locality of *D. tani nodifer*). (p. 392)
4—Lopadolith from Miocene marl, 1.6 miles S of Mafron, Haiti. (p. 393)
5—Thoracosphaera sp., Cipero formation (upper Oligocene), Retrench Quarry, Princes Town area, Trinidad. (p. 393)
6a, b—Braarudosphaera bigelowi (Gran and Braarud), Lodo formation, 135 ft. above base (lower Eocene), Lodo Gulch, Fresno County, California. *6a*, vertical view of isolated pentalith; *6b*, sketch of lateral view. (p. 393)
7—Braarudosphaera discula, n. sp., holotype. (p. 394)
8—Micrantholithus cf. *M. vesper* Deflandre, same locality as for fig. *6*. (p. 394)
9—Ceratolithus cf. *C. cristatus* Kamptner, Recent Pacific sediment at Lat. 04°35.3′N, Long. 139°57.7′W. (p. 394)
10—Discoaster multiradiatus, n. sp., holotype. (p. 396)
11—Discoaster tribrachiatus, n. sp., holotype (p. 397)



Bramlette and Riedel, Discoasters and related microfossils



Bramlette and Riedel, Discoasters and related microfossils

Recent *Rhabdosphaera claviger* Murray and Blackman. Lopadoliths, of which one of the various forms is figured on pl. 38, fig. 4, have been noted in many late Tertiary sediments, but have not been observed in rocks older than late Oligocene.

The soft parts of most of the following "form genera," which Deflandre places in his order Ortholithae, are quite unknown, and the skeletal remains of the various genera have practically nothing in common, apart from the individual parts having the optical properties of unit crystals. For these reasons, it seems premature to group them into a taxonomic order, and desirable to regard them for the present, as genera incertae sedes. Later investigations may reveal other forms (perhaps intermediate between known "genera") providing a sounder basis for a classification.

Genus THORACOSPHAERA Kamptner
Plate 38, figure 5

Small, spherical tests assigned to this genus are found very commonly in Tertiary strata. Although the tests have been found in Recent sediments, the living organism has not been described.

The spherical tests often have a "buccal opening." Deflandre's investigations led him to the conclusion that the presence or absence of such an opening is not an important taxonomic character, and our observations tend to confirm this view. The classification of members of this genus should probably be based in part on the nature of the individual plates forming the test. The plates of all of the specimens which we have observed are irregular in shape (pl. 38, fig. 5) and imperforate, in contrast to the polygonal, perforate plates of the figured specimen of *Thoracosphaera heimi* (Kamptner, 1927, fig. 6). Thus our form resembles *T. imperforata* Kamptner (1946) in the imperforate plates but not in the shape of the plates.

No discrimination of species has been attempted here, and the genus seems to extend from the Recent back to the Cretaceous.

Genera BRAARUDOSPHAERA Deflandre and MICRANTHOLITHUS Deflandre
Plate 38, figure 7, 8

These two genera of Deflandre (1947, 1950) comprise his family Braarudosphaeridae ("shell consisting of pentaliths, elements consisting of five pieces of crystalline calcite with characteristic orientation"). The typical test of *Braarudosphaera* has the form of a regular dodecahedron, composed of 12 pentaliths. *Braarudosphaera* contains two previously described species, *B. bigelowi* (Gran and Braarud) and *B. deflandrei* Lecal, distinguished on the orientation of the segments of the pentalith, and *Micrantholithus* contains two species (*M. flos* Deflandre and *M. vesper* Deflandre) which are differentiated apparently on the general form of the segments of the pentalith. *Micrantholithus* might better be considered merely as a subgenus of *Braarudosphaera*.

BRAARUDOSPHAERA BIGELOWI (Gran and Braarud) Deflandre
Plate 38, figures 6a, b

The isolated pentaliths characteristic of this species have been observed throughout

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EXPLANATION OF PLATE 39

All illustrations ×2500.

FIGS. *1—Discoaster tani*, n. sp., holotype. (p. 397)
2—Discoaster tani nodifer, n. subsp., holotype. (p. 397)
3a, b—Discoaster lodoensis, n. sp. *3a*, vertical view of holotype; *3b*, sketch of lateral view. (p. 398)
4—Discoaster saipanensis, n. sp., holotype. (p. 398)
5a, b—Discoaster barbadiensis Tan, sens. emend. *5a*, vertical view of pleisotype; *5b*, slightly oblique lateral view. (p. 398)
6—Discoaster deflandrei, n. sp., holotype. (p. 399)
7—Discoaster aster, n. sp., holotype. (p. 400)
8a, b—Discoaster woodringi, n. sp. *8a*, vertical view of holotype; *8b*, lateral view. (p. 400)
9—Discoaster perplexus, n. sp., holotype. (p. 400)
10—Discoaster challengeri, n. sp., holotype. (p. 401)
11—Discoaster pentaradiatus Tan, sens. emend., plesiotype. (p. 401)
12—*Discoaster brouweri* Tan, sens. emend., Miocene marl, road cut at US Agric. Field Station at Mafron, Hati. (p. 402)

the Tertiary and in Cretaceous strata. Deflandre reports it as occurring in Recent sediments but we have not yet observed it here. There would seem to be some question about the identity of the original *Pontosphaera bigelowi* Gran and Braarud (1935) and the forms figured by Deflandre under this specific name. The original figure of this species does not show the characteristic five segments forming the pentaliths.

Braarudosphaera discula Bramlette and Riedel, n. sp.
Plate 38, figure 7

Pentaliths nearly round, tending to be more or less pentagonal in shape, with the sutures between the five segments reaching the margin at or very near the angles of the pentagon. The individual segments of the pentaliths show crystallographic orientations resulting in a similar extinction order to *B. bigelowi*, between crossed nicols. Diameter usually 6–9 microns.

Type locality.—Universidad formation (middle or lower Eocene), Loma Principe, Ave. de los Presidentes, Havana, Cuba.

This species differs from *B. bigelowi* in the more rounded form of the pentaliths and position of the sutures. Its stratigraphic range has not been established, but it seems to be common only in the Eocene and particularly in the lower-middle Eocene.[1]

Micrantholithus cf. M. vesper Deflandre
Plate 38, figure 8

This form has been observed only in the Capay stage (lower Eocene) of the Lodo formation of California and in the basal part of the Plaisance limestone (middle or lower Eocene) of Haiti. *M. vesper* was originally described from the lower Lutetian of Donzacq (Landes), France.

[1] Note: After submitting manuscript, Deflandre called our attention to a rather similar form recently described as *Pemma rotundum* by B. Klumpp in Paleontographica, Bd. 3, abt. A, Stuttgart, Sept. 1953. We believe this form should also have been referred to the genus *Braarudosphaera*, but it appears to be a different species in having, on each segment of the pentalith, a central "Knopf mit einer feinen Durchbohrung."

Genus Ceratolithus Kamptner
Plate 38, figure 9

In this genus (or manipule of Deflandre) are placed small calcareous bodies shaped like horse-shoes with pointed ends, which are very common in Recent sediments and evidently occur, though sporadically, as far back as the Miocene. Judging from their widespread distribution in Recent deep-sea sediments, it appears that they are the remains of planktonic organisms which flourish in the warmer seas. The forms which we have observed all resemble *C. cristatus* Kamptner, and it is doubtful that specific distinctions can be made.

Genus Discoaster Tan

This "form genus" name is assigned to all discoasters—small, calcareous, stellate or rosette-shaped plates, derived from some planktonic organisms presumably related to the coccolithophores.

Tan Sin Hok has been the only worker seriously to attempt taxonomic work within this group, and his classification has in general been used by later workers (Deflandre, Colom, etc.) though not followed here. He divided the discoasters into three "genera" within a family Discoasteridae.

1. *Heliodiscoaster:* Rosette-shaped forms, with the arms (sectors) not separated from one another; they completely fill the disc.
2. *Eudiscoaster:* Star-shaped forms, all of the arms of which are distinct from one another at the center of the disc, at least on one surface. Number of arms varies from five to eight.
3. *Hemidiscoaster:* Star-shaped forms in which groups of arms are united to one another. The arms usually joined at angles of 120° in two groups of three each.

Within each of these "genera," species were distinguished on the basis of the number of rays and the presence or absence of a central knob. Varieties were distinguished on the basis of the width of the arms and the nature of the terminations.

The distinction of a genus *Hemidiscoaster* based on the type of union of the arms (as two triradiate forms superposed at the center of the asterolith) appears to us to be inapplicable. In an assemblage of six-rayed

forms, one occasionally finds individual specimens showing the "*Hemidiscoaster*" character (two groups of three rays united at 120°) while otherwise identical specimens from the same locality show no such grouping of the arms. Also, it seems that the distinction of genera (*Heliodiscoaster* from *Eudiscoaster*) on the basis of the number of arms is not possible. Several distinctive forms of *Discoaster*, particularly from the lower Tertiary, have 8–13 arms, and can therefore not be placed in one or another of Tan's genera. We shall therefore consider all of the discoasters as belonging to the genus *Discoaster*. This genus can be attributed to Tan Sin Hok (1927), because although formally defining his three separate genera, he used these generic names in the sense of sub-genera; he refers, for example, to "*Discoaster Barbadiensis* nov. spec." and "*Discoaster Hilli* nov. spec.," which he places in the genera *Heliodiscoaster* and *Eudiscoaster*, respectively.

Definition of the species of *Discoaster* presents many problems. Tan distinguished species primarily on the number of rays, which is apparently a useful taxonomic character, although most species exhibit considerable ranges of variation in this respect. Species with 10–15 rays often show a range of variation of two or three on either side of the mean, species with usually six rays have not been observed to vary beyond the limits of five to seven, and a three-rayed form seems never to deviate from this number. Some six-rayed forms (such as *D. deflandrei*) occasionally show rare, abnormal variations with as many as eight rays, and others (e.g., *D. challengeri*) vary abnormally to three rays, but these are regarded as teratological cases which need not be considered taxonomically. In spite of the fact that the number of rays is an important taxonomic character, the exact number cannot be given the importance indicated by Tan in his definition of species of *Eudiscoaster*, where all of the eight or nine-rayed forms were grouped into one species, the six-rayed forms into another, and the five-rayed forms into the third species.

The nature of the terminations of the arms, used by Tan for the differentiation of infraspecific groups (as in his varieties of *D. brouweri* and *D. molengraaffi*), is considered in the present paper as one of the more important characters of specific rank. The terminations of the arms of the discoasters may be undifferentiated (rounded or abruptly truncate, as in *D. brouweri* s.s. or *D. perplexus*), sharply pointed (e.g., *D. lodoensis*) or bifurcate. The nature of the terminal notching or bifurcation of the arms seems a relatively constant and important character: in *D. pentaradiatus* the two terminations are pointed in such a manner that there is little difficulty in distinguishing six-rayed examples of this species from *D. challengeri* in which the terminations are rounded, and in *D. deflandrei* the outlines of the terminal bifurcations tend to have a peculiar subangular character which is quite different from the rounded terminations of thick-rayed examples of *D. challengeri*. Some forms (particularly in late Tertiary sediments) are observed having one branch of the bifurcation much more strongly developed than the other (text fig. 2), a character which appears to a certain extent in *D. pentaradiatus*. Apart from the cases of simple bifurcation, forms have been observed which have three prongs at the end of each arm: these forms have not been considered in this paper, although this characteristic branching may later prove to be of taxonomic value.

In a few forms, the arms bear lateral projections which are at least sufficiently constant to be considered as of some taxonomic value (as in our *D. tani nodifer* and perhaps in the undescribed *D. mirus* of Deflandre, 1952b, p. 465, fig. 362 Z). Width of the arms, which is often related in a general way to the overall robustness of the whole asterolith, is an important taxonomic feature, although it varies within moderately wide limits for each species. Two factors which may cause some of the variation of this character within a species are the amount of calcium carbonate available to the organism in its marine environment, and the stage of development of the organism (an immature asterolith may tend to have thinner arms than an older example). The effects of these factors are impossible to evaluate at present, especially as we have practically no information on the type of organism which produces the asteroliths. Despite these uncertainties, it is possible to define the width of the rays of each species

within reasonable limits, and in some cases to use this character to assist in the distinction of species: for example, *Discoaster pentaradiatus* has thinner arms than *D. challengeri*, which it resembles in many other respects. It may be mentioned that there is a tendency for the rays of some of these six-rayed forms to become progressively thinner from the early to the late Tertiary, but the significance of this must remain a matter of speculation.

The structure of the central area of discoasters is often difficult to determine, because the asterolith has to be examined in side view, and some of the characters are so small as to be near the limit of resolution of an ordinary microscope. The most common modification of the central area is its growing outward to form a type of knob or stalk, which may be quite prominent, as in *Discoaster barbadiensis*, or small and inconspicuous as in some examples of *D. challengeri*. Sometimes the stalk appears stellate in vertical view; many specimens of *D. tani*, for example, show a central star, the points of which alternate with the arms. Although the presence or absence of a central knob or stalk is sufficiently constant to be used as a diagnostic feature of some species (as *D. barbadiensis*), there are other species (e.g., *D. multiradiatus*) of which some specimens in a given assemblage have a small knob, while in others it is not apparent. This may be the result of dimorphism of the asteroliths on individual organisms, of which there are many examples in the typical coccolithophores.

Finally, there are many discoasters in which the arms are not in a single plane, but curved like the ribs of an umbrella (text fig. 3b). This bending of the arms is a rather constant feature in species such as *D. tani*, *D. brouweri*, and some others. Deflandre (1952b, p. 476, 468) has pointed out that this may indicate that the discoasters covered the outer surface of a spherical organism, as do coccoliths.

DISCOASTER MULTIRADIATUS Bramlette and Riedel, n. sp.
Plate 38, figure 10

Asterolith rosette-shaped, consisting of usually 16–24 rays joined throughout their length though depressed along the sutures and bluntly pointed distally to produce a serrate margin. Central area of both faces often shallowly depressed, with usually a very small knob or stem in the center. Total diameter usually 9–15 microns.

This species differs from *D. barbadiensis* in the greater number of rays, and in being more nearly complanate and thinner in proportion to the diameter. It differs from *D. perplexus* in the greater diameter and serrate margin.

Type locality.—Velasco shale (Paleocene or uppermost Cretaceous), 500 meters N 70° W of Estacion Velasco, approximately 75 km. W of Tampico, Mexico.

Other occurrences.—Lodo formation (Paleocene, Zone D of Laiming, 1940, p. 551), Lodo Gulch, Fresno County, California; Lizard Springs formation (Paleocene or uppermost Cretaceous) Lizard Springs, Trinidad; Waipawan Stage (Paleocene), Hawke Bay, North Island, New Zealand; Scripps Mid-Pacific Sample no. MP-33C (Paleocene of Hamilton, 1953, p. 207), central Pacific.

Discussion.—This species seems to be restricted to the Paleocene, though some of the occurrences may prove to be of uppermost Cretaceous age.

Tan Sin Hok (1927, p. 118, fig. 2) figured a form resembling *D. multiradiatus* under the name *Discoaster ehrenbergi*, a species which he characterized merely as having 11 to 21 arms, without "kern." We have been unable to find such a specimen on re-examination of Tan's original samples, and moreover he figures two different forms under this name without giving any indication of where the specimens were found. Our species differs from that figured by Tan in the definite differentiation of the central area.

Besides varying considerably in total diameter, the number of rays, and the nature of the central area, as indicated in the above description, examples of *D. multiradiatus* vary in thickness. For example, specimens from Scripps Mid-Pacific Sample No. 33C are generally thicker than those from the type locality and other occurrences.

Some coccoliths superficially resemble *D. multiradiatus*, especially if somewhat corroded, but they are generally smaller and more delicate. In any questionable case, the structure as reflected by optical characters is quite diagnostic (p. 391).

DISCOASTER TRIBRACHIATUS Bramlette and Riedel, n. sp.
Plate 38, figure 11

Asterolith triradiate, consisting of three subcylindrical, commonly slightly tapering rays which are bluntly truncate and with or without a small terminal notch. Rays generally bent like those of *D. tani* and *D. brouweri*. Total diameter usually 8–13 microns (the type specimen is unusually large).

Tan Sin Hok (1927, p. 121) has named, but quite inadequately described, a *D. triradiatus* with two varieties. Examination of topotype material shows, however, that these are abnormal variations of other described species such as his *D. brouweri* and our *D. challengeri;* forms similar to *D. tribrachiatus* are not found in the material from Rotti.

Type locality.—Lodo formation (Capay stage, lower Eocene, Zone C of Laiming, 1940, p. 550), 314 ft. above base of Lodo formation, Lodo Gulch, Fresno County, California.

Other occurrences.—Lower part of Plaisance limestone (middle or possibly lower Eocene), 8 miles NW of San Michel, Haiti; Ramdat formation (lower Eocene), San Fernando area, Trinidad.

Discussion.—This characteristic species has been found at only a few localities, but these seem to be of approximately the same age, near the boundary between the lower and middle Eocene.

D. tribrachiatus is evidently not an abnormal triradiate development of any of the species with 6 rays. It somewhat resembles the six-rayed *D. tani*, but is an earlier form and is not found associated with the latter species.

DISCOASTER TANI Bramlette and Riedel, n. sp.
Plate 39, figure 1

Asterolith with five rays, but in some localities dominantly six. Rays rather heavy and of almost uniform width, abruptly truncate. The squared-off end of the ray commonly has a small notch, which in specimens from some localities is inconspicuous or absent. Small nodes are occasionally present on the sides of some rays, but these are seldom paired and not consistently developed on each ray as in the subspecies *nodifer*. The rays are generally bent like the ribs of an umbrella. Total diameter usually 9–15 microns.

This species differs from *D. brouweri* in the relatively heavy and stubby rays, the sporadic occurrence of lateral nodes, and commonly in the presence of a slight terminal notch on the rays.

Type locality.—Densinyama formation (upper Eocene), E side of Talofofo Road, S 80°E 1600 ft. from junction of Talofofo Road and Ridge Road, N Saipan.

Other occurrences.—Hospital Hill marl of the San Fernando group (upper Eocene), Hospital Hill, Trinidad; Waiarekan formation (upper Eocene), Cormack's Siding, W of Oamaru, New Zealand; Oceanic formation (upper Eocene), Bath, Barbados; Gatuncillo formation (upper Eocene), 2.7 miles NW of Rio Quebrancha Bridge, Panama Canal Zone; Ledian blue marl (upper Eocene), Cote des Basques, Biarritz, France.

Discussion.—This widespread species is common in the upper Eocene, but some evidence suggests that it may occur also in middle Eocene and lower Oligocene sediments. A central knob is apparent in some specimens, and this occasionally shows a peculiar star shape in vertical view.

D. TANI NODIFER Bramlette and Riedel, n. subsp.
Plate 39, figure 2

Asterolith differing from the typical form in the presence of distinct paired nodes on each ray, and usually in slight enlargement of the ends of the rays and more conspicuous terminal notches. It appears generally to have less bent arms than the typical form. Total diameter usually 13–18 microns.

Type locality.—Jackson formation (upper Eocene), 3½ miles SE of Isney, on the road to Silas, Alabama.

Other occurrences.—Waiarekan formation (upper Eocene), Cormack's Siding, W of Oamaru, New Zealand; Hagman formation (upper Eocene), Saipan, Marianas Islands.

Discussion.—The limited data suggest that this subspecies is more definitely restricted to the upper Eocene than is *D. tani* s.s. This subspecies never constitutes such a conspicuous element of the assemblage as does the typical form. It seems desirable to differentiate this subspecies because it does

not occur with abundant *D. tani* in many localities, and it seems to be the only form of this species in a few other localities; also, it appears to be more restricted in range.

DISCOASTER LODOENSIS Bramlette and Riedel, n.sp.
Plate 39, figures 3a, b

Asterolith stellate, consisting of usually six (occasionally five or, rarely, seven) rays which are joined in their proximal half or one-third. Free, distal portions of the rays tapering gradually to a sharp point, and curved, all in the same sense, in the plane of the body of the asterolith. Centrally, a stem or knob projects from one surface. On the same side of the asterolith as the stem, each ray is raised as a prominent ridge extending radially to one side of the median line: the other side of the asterolith is more nearly plane. Total diameter usually 14–24 microns.

This species differs from *D. saipanensis* in the longer, thinner, and more curved arms.

Type locality.—Lodo formation (Capay stage, lower Eocene, Zone C of Laiming, 1940, p. 550), 314 ft. above base of Lodo formation, Lodo Gulch, Fresno County, California.

Other occurrences.—Lower Lutetian, Donzacq (Landes), France; lower part of Plaisance limestone (middle or possibly lower Eocene), 8 miles NW of San Michel, Haiti; Ramdat formation (lower Eocene), San Fernando area, Trinidad; Toledo member of Universidad formation (lower or middle Eocene), Cantera San Francisco, Puentes Grandes, Habana Province, Cuba.

Discussion.—This species may prove to be rather narrowly restricted to the upper part of the lower Eocene and the lower part of the middle Eocene. Specimens from some of the localities mentioned, particularly from Donzacq, have somewhat wider, straighter rays than those from the type locality, thus somewhat approaching *D. saipanensis*.

DISCOASTER SAIPANENSIS Bramlette and Riedel, n.sp.
Plate 39, figure 4

Asterolith stellate, with usually six or seven (rarely five or eight) straight rays which are joined for approximately half their length and taper distally to sharp points. Centrally, a stem or knob projects from one surface. Each ray has a prominently raised ridge extending radially to one side of the median line. Total diameter usually 9–13 microns.

Though this species shows similarities to both *D. barbadiensis* and *D. lodoensis*, the relationships were not sufficiently clear to assign it as a subspecies to either. It differs from *D. barbadiensis* in the more-separated and more sharply pointed rays, and the smaller number of rays. The differences from *D. lodoensis* have been pointed out in the discussion of that species.

Type locality.—Densinyama formation (upper Eocene), E side of Talofofo Road, S 80°E 1600 ft. from junction of Talofofo Road and Ridge Road, N. Saipan.

Other occurrences.—This species is very common in upper Ecoene samples from widely scattered localities.

DISCOASTER BARBADIENSIS Tan sens. emend.
Plate 39, figures 5a, b

"Krystaldrusen," EHRENBERG, Mikrogeologie, pl. 24, fig. A 67, pl. 25, figs. B 13 and 15, Leipzig, 1854.
"Crystalloids," JUKES-BROWNE and HARRISON, Quart. Jour. Geol. Soc., vol. 48, p. 178, figs. 4–6, 1892.
Discoaster barbadiensis TAN SIN HOK (in part), Jaarb. van het Mijnwezen in Ned. Oost-Indië, 1926, p. 119, 1927.
Heliodiscoaster barbadiensis Tan. DEFLANDRE, Bull. Soc. Francaise Microscopie, vol. 3, no. 2, p. 64, figs. 22 and 23, 1934.
Hemidiscoaster barbadiensis (Tan). COLOM and GAMUNDI, Estudios Geologicos, Madrid, no. 14, pl. 25, 1951.

Asterolith mushroom shaped, with a concavo-convex disc consisting of usually 9–13 rays, bearing a prominent stem on its concave surface. Rays joined throughout their length, with rounded or bluntly-pointed tips forming a serrate margin to the disc. Stem approximately conical, rounded distally. Total diameter usually 9–17 microns.

This species differs conspicuously from *D. multiradiatus* in the constant presence of a stem and fewer rays, and is equally distinct from *D. lodoensis* in the character of the rays, even though the latter has a stem.

Plesiotype locality.—Near middle of Oceanic formation (upper Eocene) at Bath, Barbados.

Other occurrences.—This species occurs in almost every Eocene assemblage examined, comprising nearly 100 samples from such widely scattered regions as California, Saipan, New Zealand, several Caribbean islands, France, Tunisia, etc.

Discussion.—Discoasters conforming to the emended description appear to be restricted to the Eocene and Paleocene (small and rare in the latter). The considerable range of variation of this species in different parts of the Eocene may make it desirable to differentiate some subspecies. For example, the small forms occurring very low in the Eocene should perhaps be distinguished taxonomically from the later forms, not only on account of their size, but also because of their relatively robust stem.

Tan Sin Hok's description of this species, "with 11 to 21 arms (sectors), which completely fill in the disc. In the centre, the arms are extended axially to form a 'kern.' Total diameter 15 microns, and smaller," was apparently based on the figures of Ehrenberg (1854) and Jukes-Browne and Harrison (1892), and perhaps on some specimens which he found in the sediments at Rotti, near Timor. We were unable to find specimens resembling *D. barbadiensis* on re-examination of portions of Tan's original samples, although a single specimen which conformed to his *D. barbadiensis* var. *bebalaini* was found. This small "variety" would not seem to be closely related to *D. barbadiensis*, principally because of the lack of a prominent stem.

The figures of Jukes-Browne and Harrison do not show the pronounced concavity on the side of the asterolith which bears the stem, and while this may be the case in some specimens, it is found that the shape is generally as shown in our figures. Assignment of our specimens to Tan's species seems justified because examination of many individuals from many samples of the Oceanic formation of Barbados indicates that the original figure of the side view was poor or of an abnormal specimen.

Reworking into later sediments of this abundant and ubiquitous form is evidently common, and seems to account for the reported occurrences in the Haitian Oligocene (Deflandre) and the Aquitanian-Burdigalian of Majorca, Spain (Colom and Gamundi) (see p. 390).

DISCOASTER DEFLANDREI Bramlette and Riedel, n.sp.

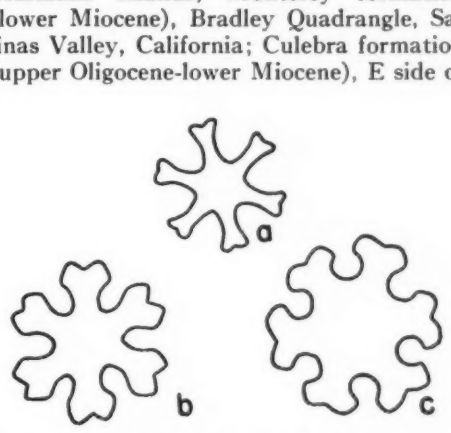
Plate 39, figure 6; text figures 1 a, b, c

Asterolith consisting of a central disc with usually six (rarely five or seven) broad, bifurcate rays which are generally as long as, or a little longer than, the radius of the central disc. Outline of the enlarged, bifurcating parts of the rays rounded or slightly angular; terminal notches angular rather than rounded. Spaces between the rays (proximally) subcircular, not angular, approximately as broad as the narrowest part of the rays and half as broad as the widest part of the rays. Total diameter usually 10–17 microns.

This species differs from *D. challengeri* in the large central disc and relatively broad rays, with the sides of the rays not parallel; and from *D. woodringi* in the bifurcate rays with rounded spaces between them.

Type locality.—Cipero formation, Renz sample no. 90, type locality for the fauna of Zone I (lower Oligocene of Renz and of Cushman and Stainforth, 1945, p. 4), sea cliffs south of San Fernando, 375 ft. S of 35½ mile-post on railway, Trinidad.

Other occurrences.—Burdigalian (lower Miocene), Saint-Etienne d'Orthe, Aquitaine Basin, France; "Adelina marl" (lower Oligocene of Palmer and Bermudez, 1936, p. 227), Finca Adelina, E of Colon, Matanzas Province, Cuba; Densinyama formation (upper Eocene), Talofofo Road, N Saipan, Marianas Islands; Monterey formation (lower Miocene), Bradley Quadrangle, Salinas Valley, California; Culebra formation (upper Oligocene-lower Miocene), E side of



FIGS. *1a–c—Discoaster deflandrei*, n. sp., ×1650, showing variation in width of rays. *1a, b*—From the Eocene of Saipan. *1c*—From the Burdigalian of the Aquitaine Basin, France.

Gaillard Cut near Empire Bridge, Panama Canal Zone, and many other localities.

Discussion.—This species apparently ranges from the middle Eocene to the lower Miocene, inclusive, but is abundant only in the Oligocene. The considerable range of variation, particularly in the width of the rays, may make it desirable eventually to recognize several subspecies or varieties (text figs. 1a, b, c).

DISCOASTER ASTER Bramlette and Riedel, n.sp.
Plate 39, figure 7

Discoaster stella (Ehrenberg). COLOM and GAMUNDI, Estudios Geologicos, Madrid, no. 14, pl. 25, fig. 6, 1951.
not *Discoaster stella* (Ehrenberg). DEFLANDRE, Traité de Zoologie, vol. 1, fasc. 1, p. 465, figs. Y–Y″, 1952.

Asterolith stellate, with commonly five or six, rarely seven thick and wide rays which vary markedly in width and degree of separation, and terminate in a rounded or bluntly pointed tip. The rays are somewhat irregular in outline due to their rather rugose surface. Total diameter usually 8–20 microns.

Type locality.—Near top of Oceanic formation (lower Oligocene) at Bath, Barbados.

Discussion.—This rather nondescript and very variable species may actually include several unrelated forms, and the variability makes it difficult to separate the extremes from the usually much thinner-rayed *D. brouweri* on the one hand and *D. woodringi* on the other. Also, it varies greatly in size, including a very small form in the earliest Tertiary which is otherwise indistinguishable from the later, larger forms.

Colom and Deflandre have both applied Ehrenberg's name "stella" to somewhat similar discoasters, but *Actiniscus stella* Ehrenberg is a name which should properly be applied to a siliceous microfossil. It appears that Ehrenberg generally distinguished sharply between siliceous and calcareous fossils. There is some possibility that he also used the name *Actiniscus stella* for calcareous skeletal remains (e.g., Ehrenberg, 1854, pl. 20, fig. 47) although the original reference was evidently to a siliceous microfossil.

D. aster is widely distributed geographically, and occurs throughout the Tertiary, and possibly in the Quaternary in which occur rare specimens of rather similar form.

DISCOASTER WOODRINGI Bramlette and Riedel, n.sp.
Plate 39, figures 8a, b

Discoaster brouweri var. *delta* Tan Sin Hok. DEFLANDRE, Bull. Soc. Francaise Microscopie, vol. 3, no. 2, text-figs. 20, 21, 24 (not 25), 1934.

Asterolith discoidal, robust, consisting of usually six (rarely five) thick, almost triangular rays. The thickness of the asterolith is approximately half the diameter. Rays joined throughout their length, except where separated by rounding of distal margins, and bounded by prominent sutures extending to the center. Total diameter usually 11–14 microns.

This species differs from *D. aster* in the greater width, and less separation and blunter termination of the rays, though many forms in some samples appear to be intermediate between the two.

Type locality.—Marl from Locality 0–1 of Hadley (1934) (lower part of Oligocene), 50 meters SW of gate to Naval Academy, Mariel, Cuba.

Other occurrences.—Chalky marl (Oligocene), sea cliff along highway, ½ mile SE of plaza in Jeremie, Haiti; Densinyama formation (upper Eocene), Talofofo Road, N. Saipan, Marianas Islands; top of Oceanic formation (lower Oligocene) at Bath, Barbados; Zone II of Cipero formation (upper Oligocene), Retrench Quarry, Princes Town area, Trinidad; and in many other widely scattered localities, mainly Oligocene in age.

DISCOASTER PERPLEXUS Bramlette and Riedel, n.sp.
Plate 39, figure 9

Asterolith small, thin, discoidal, with circular outline modified only by the straight distal margins of the rays. Rays usually 11 or 12, occasionally 10 or 13, very elongated triangular, joined throughout their length and marked by sutures which are rather inconspicuous except under the phase-contrast microscope. Total diameter generally 6–10 microns.

This species differs from *D. multiradiatus* in smaller size, flat surface of the rays and therefore less obvious sutures, and lack of serrate margin. In its size and general form,

it more closely resembles some coccoliths.

Type locality.—Cipero formation (Zone II, upper Oligocene, Renz sample no. 555), Retrench Quarry, Trinidad.

Discussion.—This small, rather nondescript form was overlooked during most of this investigation, and was not distinguished from the numerous forms of coccoliths. However, it obviously does not belong with the coccoliths because it shows the optical properties of a single calcite crystal, as do all the discoasters. It was observed in a few other samples of middle Tertiary age, but was not recorded.

DISCOASTER CHALLENGERI Bramlette and Riedel, n.sp.

Plate 39, figure 10

Discoaster molengraaffi var. γ TAN SIN HOK, Jaarb. van het Mijnwezen in Ned. Oost-Indië, 1926, p. 121, text-fig. 2 (11), 1927.

Discoaster. TAN SIN HOK, ibid., p. 111, text-fig. 1 (3).

Discoaster to upper right of center of figure. MURRAY and RENARD, Report on Deep-Sea Deposits, based on specimens collected during the voyage of H.M.S. *Challenger*, pl. 11, fig. 4, 1891.

Asterolith with usually six (occasionally five or rarely seven) rays which are subcylindrical, distally bifurcate into short, rounded terminations. Rays show little or no curvature of the type found in *D. brouweri*. Widening of rays in central area never pronounced; central area with or without a small, circular knob. Rays typically thin, but varying considerably in width. Total diameter generally 10–13 microns.

D. challengeri differs markedly from *D. deflandrei* in the thin rays of uniform width and generally more delicate structure. The distinction from *D. pentaradiatus* is discussed under that species.

Type locality.—Lengua formation (lower Miocene), E side of Lengua Settlement Road, about 60 yds. from junction with Realize Road, approximately three miles S of Princes Town, Trinidad.

Other occurrences.—Suva formation (Miocene), just north of hospital, Suva, Fiji; chalk (late Tertiary), Bebalain, Rotti, East Indies (Sample no. 168 of First Netherlands Timor Expedition); Bowden (?) formation (middle ? Miocene), Buff Bay, Jamaica; Tagpochau limestone (lower Miocene), Saipan, Marianas Islands; and many other widespread Miocene localities.

Discussion.—This species is abundant and of widespread occurrence in the Miocene, and also occurs in probable upper Oligocene (as in the upper part of the Cipero formation, Trinidad) where it is however generally represented by more robust forms which it may prove desirable to distinguish as a separate subspecies.

The upper limit of its occurrence is questionable, as virtually no Pliocene material is available. The assumption of its occurrence in the Recent, made first by Tan Sin Hok on the basis of its occurrence (with his type *D. molengraaffi*) in a *Challenger* sample (Murray and Renard, 1891) seems doubtful. Neither form has been recorded or observed by us in other purely Recent deposits, though they are present in surface samples where other evidence indicates reworking. The probability of its occurrence at *Challenger* Station 338 being due to reworking has been discussed above (p. 389).

DISCOASTER PENTARADIATUS Tan sens emend.

Plate 39, figure 11; text figures 2a, b

Discoaster pentaradiatus var. γ TAN SIN HOK, Jaarb. van het Mijnwezen in Ned. Oost-Indië, 1926, p. 120, text-fig. 2 (14), 1927.

Asterolith with five (though perhaps as commonly six) thin rays having bifurcations which are characteristically sharp and delicate. The distal margin of the ray between the bifurcation is a smooth curve, in contrast to the more angular notch of *D. challengeri* and *D. deflandrei*. On each ray, one branch of the bifurcation is commonly longer than the other. As in *D. challengeri*,

FIGS. *2a, b—Discoaster pentaradiatus* Tan Sin Hok, sens. emend., ×1650. *2a*—Specimen from Rotti, near Timor (after Tan Sin Hok, 1927). *2b*—Specimen from the Miocene of Haiti, showing long and unequal bifurcate points.

the rays normally show little of the type of bending characteristic of *D. brouweri*. Total diameter usually 9–12 microns.

Plesiotype locality.—Marl (Miocene), 1.6 miles S of Mafron, Haiti.

Discussion.—The central area of the asterolith is usually more enlarged than indicated in Tan's figure (figs. 2a, b). Tan indicates, without further discussion or figures, that this species has several varieties corresponding to those of his *D. brouweri*. Any such entirely different forms could hardly be included in *D. pentaradiatus*, for the reasons outlined in the discussion of *D. brouweri*.

Restriction of this species to five-rayed forms seems unjustified, and distinction from *D. challengeri* therefore becomes somewhat difficult in some occurrences, because the latter species can also have five rays. The character of the bifurcations and the delicate structure are considered more diagnostic features.

This species is widespread in Miocene strata, and has not been observed below the Miocene. The upper limit of its occurrence is not known, as almost no Pliocene discoaster assemblages are available, and it apparently does not occur in the Recent. Typical forms occur in the Lengua formation of Trinidad, Suva formation of Fiji, the Tagpochau limestone of Saipan, and at many other localities.

DISCOASTER BROUWERI Tan sens. emend.
Plate 39, figure 12; text figures 3a, b

Discoaster brouweri typ. TAN SIN HOK, Jaarb. van het Mijnwezen in Ned. Oost-Indië, 1926, p. 120, text-fig. 2 (8a, b), 1927.

FIGS. *3a, b—Discoaster brouweri* Tan Sin Hok, sens. emend., ×1650. *3a*—Vertical view of a specimen from Rotti, near Timor. *3b*—Lateral view of a specimen from the Suva formation, Fiji.

Discoaster molengraaffi typ. TAN SIN HOK, ibid., p. 120, text-fig. 1 (9), 1927.

?Discoaster aff. *D. brouweri* Tan. DEFLANDRE, Bull. Soc. Francaise Microscopie, vol. 3, no. 2, p. 66, text-figs. 15–19, 1934.

Tan Sin Hok (1927) described this species to include several very different six-rayed forms of his genus *Eudiscoaster*. Apart from the typical form, he recognized the four varieties α (club-shaped termination of rays), β (very broad rays, notched terminally), γ (rays less broad terminally, thickened and somewhat notched) and δ (broad rays not separated, but asterolith margin serrate by indentations at the sutures and by notching at the ends of the rays). Some of his varieties are so distinct in appearance and occurrence from the typical form that they are assigned to new species described here. We restrict his species to the typical form, which is the dominant form in his original samples (see his pl. 3, fig. 1). *D. molengraaffi typ.* Tan Sin Hok, which was based on a figure from a sample of the *Challenger* expedition (Murray and Renard, 1891, pl. 11, fig. 4) is considered to be identical with *D. brouweri*, sens. emend., as the generic distinction seems inapplicable (see discussion of *Hemidiscoaster*, p. 394).

The restricted species has usually six rays (occasionally five and rarely, if ever, seven) which are thin, elongate, bluntly pointed, not bifurcate; they are generally more tapering in Tan's samples than his figure indicates (see our text fig. 3a). The rays are more or less bent like the ribs of an umbrella, and this character can become extreme in certain occurrences (e.g., text fig. 3b, from the Miocene of Suva, Fiji). The examples in Tan's original material show less proximal enlargement of the rays to form a slightly expanded central area than do the usual forms which we include in this species. Perhaps some of the forms, for this reason, may later be separated as distinct subspecies.

This species is one of the most abundant and widespread forms of the late Tertiary, occurring in nearly every Miocene sample examined from both sides of the Atlantic, Mediterranean and Pacific Oceans. It also occurs, less abundantly in sediments of probable late Oligocene age, and extends up into the Pliocene.

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CULTURE METHODS IN THE STUDY OF LIVING FORAMINIFERA[1]

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ABSTRACT—The simple methods and equipment used in the preparation and maintenance of persistent mass and isolation cultures of marine Foraminifera are described.

INTRODUCTION

THERE seems to be a wide-spread notion among paleontologists that the Foraminifera are unfavorable for maintenance in laboratory cultures. The degree of facility with which representatives of the different families can be raised under laboratory conditions is certainly variable, but a variety of forms can be kept for prolonged periods with little effort and simple equipment and methods.

A variety of foraminiferal types has been maintained in laboratories since biologists first began the study of the living Foraminifera. The first half of the 19th century producted a few scattered notes on specimens from cultures and the last half of the same century produced a flood of such accounts. Gervais (1847) reported observations conducted on miliolids that had been kept in simple sea-water cultures. Schultze (1856) maintained *Triloculina* in a similar fashion and was able (1860) to keep a rotalid alive for a year and a half in his laboratory.

The classic observations of Schaudinn and Lister in the decade from 1893 to 1903 included several studies conducted on laboratory-reared specimens. Winter (1907) kept living specimens of *Peneroplis pertusus* in his laboratory and Swarczewsky (1909) conducted his brilliant studies of *Allogromia ovoidea* upon specimens which had survived the rigors of a laboratory for more than a year while left in a neglected container of Rovigno sand and water at the Zoological Institute of Munich. Hofker (1930a, 1930b) maintained *Quinqueloculina annectans* on a species of *Navicula* and conducted observations on *Rotalia beccarii* var. *flevensis* which had been kept in his laboratory aquaria. Myers (1935b) maintained *Patellina corrugata* for prolonged periods by means of the simple methods he described in 1937. He was also able by means of these techniques to maintain a variety of littoral, bottom-dwelling species of the following genera: *Discorbis*, *Pyrgo*, *Triloculina*, *Bulimina*, *Spirillina* and *Robulus* (1937). Føyn (1936) kept *Myxotheca arenilega* in cultures for several months, and Le Calvez (1938) maintained a variety of forms, including *Planorbulina mediterranensis*, *Discorbis vilardeboanus*, *Entosolenia marginata*, *Iridia lucida* and *Patellina corrugata*. Jepps (1942), continuing the tradition of Lister, conducted an intensive series of observations on *Elphidium crispum* which had been collected from the notoriously rich "White Patch" collecting grounds and reared in cultures at the Plymouth marine station.

The writer has maintained for more than seven years flourishing cultures of *Allogromia laticollaris* and a miliolid which resembles *Spiroloculina hyalina* Schulze. Specimens of *Discorinopsis aguayoi* (Bermudez) were happy for two years in the pleasant warmth of a Georgia laboratory, but after transfer to California gradually failed to reproduce and were lost from the cultures. Specimens which have been tentatively identified as *Bolivina subexcavata*, *B. vaughani* and *Discorbis columbiensis*, together with an unidentified polymorphic miliolid, have been kept in cultures for almost a year, and at the time of this writing appear to have become successfully established in their artificial environment.

The total quantity of Foraminifera that can be produced under a given set of cultural conditions varies with the species and many other factors, but some indication of

[1] A contribution from the Museum of Paleontology of the University of California at Berkeley.

the expected cultural productivity can be obtained from the observation that a 4-inch finger-bowl of *Allogromia laticollaris* frequently yields 4000 individuals, while a similar culture of *Spiroloculina hyalina* not infrequently produces several times this number.

The above records should indicate not only something of the feasibility of culturing marine Foraminifera but also the rather wide-spread success encountered by students of the group in this aspect of their studies. Most of the successful culture programs have been restricted to bottom-dwelling species from near-shore waters, but a determined effort will no doubt reveal the special treatment required for growing the more difficult forms.

Most paleontologists who have been nurtured in the tradition of uniformitarianism can appreciate the advantages of being able to keep and observe living Foraminifera in the laboratory. Our understanding of the biology of the creatures can be enhanced by watching the antics of living forms under the microscope, and as this understanding increases so should our ability to evaluate related paleontological problems.

The problems that can be investigated through the use of laboratory cultures are legion. Taxonomic involvements arising from an inadequate understanding of the range of variation within a given morphological complex can frequently be elucidated through the study of populations in culture. Arnold, through a study of such culture populations, has recently (1954) shown that forms previously known as *Discorinopsis vadescens* Cushman and Bronnimann are actually variants of *D. aguayoi* (Bermudez), that the two forms develop together in laboratory populations, and that they should, therefore, be expected to occur in natural association as well.

Clues to the evolution of foraminiferal types may well be uncovered by the study of specimens which have been maintained under laboratory conditions. A study of variation in the primitive foraminiferan *Allogromia laticollaris* (Arnold, 1953) has shown that this highly plastic species exhibits variants which show the same test form as several more advanced families, including the astrorhizids, saccamminids, trochamminids, lituolids, buliminids, cymbaloporids and rotalids. These variants may merely be isomorphs, but the observations serve to stimulate new thought on foraminiferal evolution.

The paleoecologist could learn much about the ecology of fossil foraminiferal assemblages through the study of environmental tolerances of culture populations. Myers (1935) has shown, for example, that *Patellina corrugata* has a temperature optimum which is only 4–5°C. below its upper thermal limit and that the rate of reproduction is appreciably reduced when the temperature falls below 18°C. A laboratory study conducted by the writer has shown that although *Discorinopsis aguayoi* can tolerate temperatures from near freezing to 34°C. its lower thermal limit for successful reproduction probably lies above 25°C. Experiments now in progress indicate that the small miliolid *Spiroloculina hyalina* has a temperature optimum which is much lower than the average temperature it encounters in one of its natural occurrences (the Gulf of Mexico) and suggest that it is a cool-water species which is probably living precariously near the upper thermal limit for successful maintenance of the species in that locality.

Studies of this type are of special interest to the paleontologist, but others far transcend the limits of paleontological significance and offer opportunities for the investigation of problems of fundamental importance to several other fields of biological endeavor.

Myers (1935a, 1937) has stressed the importance of choosing species for culture which have relatively short reproductive cycles; this is a primary consideration in planning a culture program. As a general rule it is best to choose the smaller species, since these are likely to have a shorter reproductive span. *Allogromia laticollaris* (Arnold, 1948), with an average diameter of 200 microns, has been found to have an asexual span of approximately two weeks, while several months may be required for the production of a single group of young in such a multilocular form as *Elphidium crispum*.

The other most valuable guiding prin-

ciples for a culture program are that productivity be high, maintenance effort low and culture ingredients, equipment and techniques simple. The methods to be described have been devised in accordance with these desiderata.

THE COLLECTION AND PRE-CULTURE PREPARATION OF SPECIMENS

The rapidly expanding store of data on occurrences of Recent Foraminifera in most of the waters of the world frequently gives good prescience of the forms that may be encountered along a given shore or sea bottom, but unless the collector knows the proposed collecting locality from personal experience it is still wise to prospect the area rather thoroughly before settling on a collecting spot. Many an ambitious student has busily collected samples along a seashore which was reputed to carry an abundance of Foraminifera, and hastened back to the laboratory to examine his samples only to find that they contained no Foraminifera or perhaps only a few empty tests. The collection of materials in the size range of most Foraminifera is not an easy task at best, and it is all too easy to overlook the most probable spots for successful collecting. A 10× hand lens or, better still, a stereoscopic microscope equipped with flashlight or a portable light of the type described by Wishart and Stovell (1948) is a decided asset, especially if one is working in an unfamiliar locality and does not know precisely where the Foraminifera are living.

The easiest areas for collecting are littoral or intertidal, since these require neither elaborate collecting equipment nor boat for their exploitation. The present discussion will be confined to such shallow-water collecting. Summaries of the gear used in collecting planktonic and benthonic samples from the open ocean are contained in the works of Sverdrup et al. (1946), Heck et al. (1932) and Phleger (1946).

The principal clues to a suitable spot for foraminiferal growth are, of course, the plants and sediments. A wave-swept stretch of sand which supports neither algae nor seagrasses will almost certainly yield nothing but empty or fragmental tests and pleasant bathing, so no effort should be expended in prospecting it. Similarly, a protected embayment with acres of plantless, muddy bottoms can be by-passed. But wherever there is a good growth of marine plants and a bottom with interspersed patches of fine organic sediment a closer examination is indicated. It is often possible to find broad expanses of marine plants in exposed stretches of sandy bottom, but the nature of the sediments indicates strong current or wave action, a contraindication of abundant foraminiferal growth. The bases or holdfasts of sea-weeds or grasses which are attached to a rocky substratum frequently contain healthy populations of Foraminifera, as do the upper portions of plants which are protected from violent wave or current action.

Some species have definite substratal preferences, and a knowledge of these individual preferences is often advantageous in the search for living forms. Myers (1943 and 1945), in an excellent account of practical collecting procedures, has described some of these preferences together with a number of important ecological clues to be sought for and utilized in collecting Foraminifera. Le Calvez (1938) found *Planorbulina mediterranensis* in abundance on *Posidonia caulini*, a form which exists in "veritables prairies sous-marines" on mud-sand bottoms. Myers obtained a good supply of *Patellina corrugata* (1935), *Tretomphalus* (1943), and *Spirillina vivipara* (1936) from coralline algae. The foraminiferoid protozoan *Gromia oviformis* has a distinct affinity for the sponge *Leuconia* in its California occurrence; in one instance a single sponge with a diameter of two inches was made to yield a bonanza of more than 200 specimens from the well-protected crevices among its spicules.

As soon as a favorable location has been determined a quick check by hand lens or microscope should give an idea of the relative abundance and types of Foraminifera present. Such a check is rarely very thorough, however, and living forms may easily be missed or confused with empty tests by the inexperienced worker. The task of distinguishing living individuals from dead ones which may have retained quantities of protoplasm or debris requires careful scru-

tiny and is exceptionally difficult to accomplish at the sea shore. Rhumbler (1935), Phleger (1946) and Walton (1952) have discussed certain techniques that have proven of value in population surveys, but it is doubtful that these are sufficiently critical to be of much use in prospecting for forms that will be introduced into laboratory cultures. It is much safer to look for actual protoplasmic activity with the higher magnifications of a compound microscope. A good rule of thumb for the seashore is: if in doubt, collect it. It is much better to carry back extraneous material which may eventually prove to contain living specimens than to go back empty handed; and more than one worker has found species developing in his cultures which were not disclosed in the sea-side examination of the raw samples.

After the initial prospecting has been completed the task becomes one of removing the specimens from their substratum and concentrating them for transfer to the laboratory.

The rather brutal procedure of washing marine plants vigorously over a suitable receptacle frequently yields a surprisingly adequate number of uninjured specimens, but some are so firmly attached to their substratum that they can successfully be removed only with extreme care and patience. *Gromia oviformis*, for example, is best collected by clipping off the section of eel-grass to which it so tenaciously clings and returning both to the laboratory where more careful trimming and persuasion may free the protozoan. Le Calvez has encountered similar difficulty in removing specimens of *Planorbulina mediterranensis* from *Zostera*.

An efficient means of washing quantities of marine plant hold-fasts and fronds should be provided for use at the seashore. An enamel pail or a canvas-covered glass bucket of the type described by Myers (1937) is good for the purpose, though each invites a degree of disaster if roughly handled by sea or collector. A canvas bucket or galvanized pail is indestructibly adequate and safe for the animals. A coarse, bowl-shaped sieve fashioned from window screening or hardware cloth can be fitted into the mouth of the bucket to retain the larger bits of plant material as water is poured over the plants, or the entire assembly can be filled with grass tufts and then completely immersed in a tide pool while the tufts are scrubbed over the screen.

An alternative method of obtaining the initial collection is to drag a fairly coarse plankton net through a likely looking area which has first been roiled to set the Foraminifera into temporary suspension. The same results can be obtained by drawing an epibenthic dredge through the area, since the dredge has an attached length of chain which precedes it and sets the bottom materials into movement. Hofker (1930) described a Bodennetz which was used in making his Naples Foraminifera collections, and Myers (1945) has described an ingeniously effective home-made dredge for the same purpose.

The Foraminifera must next be freed from as much of the unwanted debris as possible, a task which can best be accomplished in the luxury and comfort of a well-equipped laboratory, but which can also be executed with reasonably acceptable results at the seashore. For this purpose one of the simplest and most suitable tools is a round, shallow pan. Most of the superjacent water can be decanted from the sieve-bucket, leaving behind the concentrated Foraminifera and quantities of sand, mud and debris. These washings are then dumped into the pan, and a gentle rotating or vibrating motion is set up to force a separation of heavier and lighter elements. The sand grains are concentrated in the center and below the organic layer for the most part, so that the superjacent Foraminifera and organic debris can be removed with a wide-mouthed (5mm.) bulb-pipette. It is rarely feasible to attempt further separation at the seashore, since a laborious sorting job is usually indicated, but it is surprising how efficient the concentration of desired materials can be when the above technique is properly and diligently applied.

A last quick check of the concentrate can be made with the hand-lens or microscope if time and tide permit, and the concentrate should then be poured into glass jars half filled with filtered seawater. Care must be taken to avoid excessive crowding, and the

quantity of concentrate added to each jar will vary with the time required to reach the laboratory and the temperature at which the samples are kept en route. It is far better to add too little concentrate to each jar and be cramped for refrigerated storage space during the return journey than it is to add too much and foul the entire collection. If the laboratory is a short distance from the sea the Foraminifera have a fair chance of surviving rough treatment and overcrowding, but when a journey of several hundred miles awaits them they should be pampered. The volume of concentrate can safely range from one-twentieth to one-tenth the volume of sea water when a long journey is anticipated. If the laboratory is near at hand, however, it is often possible to fill canvas buckets with quantities of moist, debris-laden hold-fasts and carry them directly to the laboratory bench for cleaning and concentration.

An effort should be made, in any case, to keep the samples a few degrees cooler than the water from which they were collected until cultures can be established. A portable ice box of the type used by campers can be purchased or easily constructed for this purpose. The specimen jars should be packed in excelsior to prevent breakage, and crushed or block ice should be kept in a separate water-tight compartment. During transport the jars should be opened and shaken at 4- to 6-hour intervals to facilitate aeration, but the importance of this precaution diminishes with the storage temperature.

By using the methods described above it has been possible to transfer living specimens of *Allogromia laticollaris*, *Discorinopsis aguayoi* and a small miliolid resembling *Spiroloculina hyalina* Schulze safely across the United States by automobile. Refrigeration is not necessary for the successful transport of the first species, since unrefrigerated specimens have been successfully sent an equivalent distance by air on several different occasions.

As soon as the samples are brought into the laboratory they should be examined for evidence of fouling. It is a wise precaution to decant the sea water from each sample and replace it with unused, filtered sea water which has been suitably cooled. The typical odor of decaying organic matter in sea water must be rigorously guarded against, and any organic detritus should immediately be removed.

A mouth pipette of the type described by Myers (1933) or a simple pipette inserted into a rubber tube is very useful in the further concentration of the Foraminifera. If Foraminifera are abundant in the sample it may be easier to remove the unwanted material, but if they are scarce it is generally easier to pipette them into a separate container, leaving behind the unwanted debris. In some samples Foraminifera may be so rare as to require culturing before they can be found easily in the samples.

The other living organisms present in samples generally cause little trouble until they begin to die or multiply. Carcasses should be removed immediately to prevent decay, and if copepods or other relatively large metazoa begin to increase in number they should be dealt with very quickly. Copepods can be particularly devastating if allowed to multiply, but the adults are easily removed by taking advantage of their strong phototropism and the eggs may be removed by pipette without too much difficulty.

CULTURE CONTAINERS

Mass culture containers.—In the writer's experience finger bowls measuring 4 inches in diameter and 2 inches in depth are most efficient for general culture needs. The ratio between bottom area and total volume is favorable, the bowls are easily examined under a dissecting microscope and are not unwieldy, they store easily, require little space and, lastly, are economical to maintain. If a larger culture is lost, the time, effort and materials involved in replacing it may tax the worker's resources, especially if the laboratory is an inland one and sea water is difficult to obtain. It seems particularly desirable to use smaller dishes until adequate culture methods are developed, because many cultures may be lost before the desired results are obtained. For general purposes containers smaller than the finger bowls described above are usually not suit-

able, since they reduce the effective life of a culture, permit excessive evaporation and support only small populations at best.

Isolation culture containers.—The student who wishes for any reason to observe or maintain a strict control over a single individual will need to grow this specimen in isolation or so mark it as to make it immediately recognizable in a mass culture. Myers relocates critical specimens by means of paper indicators pasted to the outside of the container, a method which can not be used in the study of highly active forms. Jepps (1942) was able to identify individual specimens of *Elphidium crispum* by means of naturally adherent turbellarian cocoons or irregularities in the test itself.

A method which the writer has found useful in the study of some sluggish miliolid and rotalid species involves the use of small glass rings or cylinders made from glass tubing which can be placed around a given specimen in a mass culture to mark its position and segregate it from its fellows. It is generally difficult to find a distinctive feature by which a single animal can be recognized in a flourishing culture, so it is much simpler to use an artificial means of isolating it. This method has the added advantage of affording physical but not chemical isolation, a feature of some value in physiological researches. The size of the isolating device will vary with the size and energies of the isolated animal. For most smaller and relatively stationary species a ring or cylinder with internal diameter of five millimeters is adequate, but if larger species or more active individuals are employed the enclosed grazing area must be increased. This isolating procedure is most suitable for use in stabilized cultures which have a minimum of unattached algal or foraminiferal elements, and care must be exercised to prevent contamination if the isolating device is left open. In some instances it has been found practical to use covered isolating cylinders formed by cutting the bottom segment from a small-diameter shell vial and inverting this over the specimen.

Isolating devices of this type have proven singularly unsuccessful for the restriction of such agile forms as *Allogromia laticollaris*. These animals, refusing to be kept in such unpretentious prisons, quickly surmount the walls of small rings or cylinders and crawl under the walls of larger ones, so that within a few hours after segregation they have rejoined their companions to the confusion and chagrin of the observer. The rings proved slightly more useful in the study of old, less mobile specimens which had become thoroughly "bedded down" in their algal substrate.

The surest method of isolation, however, involves the transfer of individual specimens from the mass culture to separate culture containers. For cultures of single animals and their progeny of a few successive generations standard types of containers were tried, but for the routine maintenance of large numbers of such isolation lineages a container specifically designed for this purpose has been found more convenient. To prepare the isolation dish a glass vial with internal diameter of 25 millimeters is severed at a point 5 to 7 millimeters from the bottom of the vial. The resulting straight-sided dish, when made from vials of high-quality glass, is suitable for examination under a low-power compound microscope as well as the dissecting microscope and can be handled as a separate unmounted container or in groups which have been permanently mounted on glass slides or temporarily set into specially grooved masonite or fiberboard discs. The vials may be cut with a carborundum cut-off wheel, a diamond saw or the sharp edge of a well-dressed bench grinder, ground on a horizontal lap or glass plate and finished with #600 carborundum.

Several types of smaller isolation dishes, including depression slides of various sizes, are available for such studies, but most of these are practical only for materials which are to be kept for a relatively short period and are generally unsuitable for prolonged culture endeavors.

Storage containers and cabinets.—Foraminifera from warm waters may frequently be stored at room temperature on any convenient shelf, but many species require temperatures lower than this, so some accommodations must be provided for such culture storage. If maximum productivity

is to be obtained it is generally necessary to control not only the temperature but also the illumination to which the cultures are subjected, so the storage cabinet should incorporate such control facilities. The highest operating temperature of most automatic refrigerators is generally several degrees below that required for cultures of Foraminifera from temperate climes. Elaborate and expensive heating devices for use in standard electric refrigerators are on the market, but it is possible to raise the operating temperature to the desired range by making a special adjustment of the thermostat, or, more simply, by altering the door-switch of the interior light so as to make it burn continuously and furnish the necessary additional heat. A 25- or 40-watt bulb will usually raise the temperature to the 13–18°C. range generally required and the addition of an automatic defroster will appreciably reduce the amount of attention required in maintaining a constant temperature. Continual illumination is generally desirable for the production of good algal food stocks, but several means of reducing or shielding this light immediately suggest themselves.

The maintenance of isolation cultures requires the use of moist-chamber storage facilities. A satisfactory container is a dessicator with water replacing the dessicant, but any wide-mouthed jar with tightly fitting cap can be adapted for the purpose. The writer uses 25 millimeter culture dishes stored in groups of six on 6-inch masonite discs. The dishes are placed in grooved holes cut in the disc and are, therefore, quite secure. Each disc has a small central podium which allows it, when stacked, to rest on the underlying disc rather than on the isolation dishes themselves. The entire stack of discs is supported on a masonite disc which is supported by wires attached to the under-side of the lid of the moist-chamber.

FOOD

Many Foraminifera appear to be omnivorous in feeding habit, but very little is known concerning their specific nutritional requirements. Numerous species appear to subsist on unicellular algae and other organic matter in the laboratory; as a result most cultures have been established by direct and rather indiscriminate inoculation of particulate matter from the sea and eventually come to contain a mixture of algae, protozoa and bacteria. They may also contain certain metazoa, particularly nematodes and copepods, but the latter cannot be trusted in cultures and are best removed as soon as their presence is detected. Some of the protozoa and bacteria are undoubtedly ingested by the Foraminifera, as are the worms and copepods, but their value as food organisms has not been evaluated critically; since they are generally present in cultures, they may be disregarded until future research more clearly defines their role.

Non-filamentous, unicellular algae probably constitute the bulk of the foraminiferan diet. These can readily be obtained in marine collections, but considerable effort is required to prepare them adequately for use in cultures. A number of laboratories have established cultures of single diatom species, and inocula from these are often generously supplied by the persons who have established the culture. If such inocula can be obtained much effort can be saved in providing the necessary foraminiferal food.

Diatoms can be isolated from marine collections and cultivated by any one of the procedures described by Pringsheim (1946, 1951) but the process requires care, manipulatory skill and patience; a period of several weeks or months will usually be required to grow enough diatoms from such isolates to feed many cultures of Foraminifera. They should be grown in moderately weak light and at a temperature equal to the winter average of their natural habitat. Illumination of approximately 10 footcandles has proven adequate for a variety of species kept at a temperature of 14°C. by the writer.

Filamentous, unicellular algae can play an important role in the culture economy and must be given continual consideration in the culture program. A proper balance between non-filamentous and filamentous forms can insure the success of a culture, but if the correct proportions are upset the foraminiferan population soon suffers. If filamentous forms run rampant through a

culture the Foraminifera are soon overgrown, enmeshed in tight balls of algae and quickly starved, since their pseudopodial activity is inhibited. This difficulty is partially self-inflicted, since actively feeding individuals are typically so avaricious as to bury themselves in hoarded heaps of potential food material. When conditions for growth and multiplication are favorable these accumulated algae quickly overgrow the Foraminifera, shut off their pseudopodial activity and starve them in the midst of plenty.

Algal choking is a very real danger to individuals which are about to reproduce, since active ingestion stops as soon as the division of the parental cytoplasm begins and the accumulated algae can then multiply unmolested. It is often necessary to liberate entrapped young by "caesarian" operations which generally prove successful if performed as soon as the unfortunate condition develops.

If a culture is allowed to develop without filamentous algae, the non-filamentous forms frequently reproduce so profusely as to form a loose, flocculent substratum which greatly impedes the study and harvesting of the Foraminfera and may even actively inhibit foraminiferal development. Maximum diatom growth is not optimal for development of large, healthy foraminiferian populations, since such unrestrained multiplication rapidly exhausts the nutrient medium, fills it with waste products and increases the examination and harvesting difficulties. The impoverished foraminiferal populations generally encountered in cultures containing heavy algal components suggest that a direct inhibitory effect may exist, but no definitive study of this relationship has yet been undertaken. The food supply should be in the form of a thin layer of diatoms on a loose, filamentous framework, since neither a thick, lush floc of diatoms nor a swaying microscopic forest of blue-green filaments is desirable. A weak, carefully controlled growth of filamentous forms permits the formation of a smooth, firm, substratal carpet over the surface of which the Foraminifera crawl freely while feeding in safe leisure on the superficial diatoms.

In choosing food organisms for the cultures it is sometimes necessary to consider certain special requirements of the young forms. The young of species which as adults ingest complete diatoms and digest them within their test should, for example, be provided with suitably small diatoms.

There is great need for experimental investigation of the food requirements and feeding habits of the Foraminifera. They are known to ingest and apparently digest a wide variety of organic and inorganic materials if given the opportunity to do so; it is to be hoped that students will soon attempt to refine culture techniques in such a way as to take controlled advantage of these nutritional potentials.

NUTRIENT AND CULTURE MEDIA

The first task in culturing Foraminifera is to obtain a good supply of unicellular algae as food organisms, but these must be grown in a medium which is not harmful to the Foraminifera. Some of the numerous media available for this purpose are discussed in the accounts by Galtsoff (1937), Bold (1942), and Pringsheim (1946, 1951).

The writer has found that in general a nutrient medium which has been enriched with earth extract and added to properly aged sea water yields highly satisfactory results in the production of good stocks of algae and the maintenance of a wide variety of foraminiferal species. Some attempts have been made to use artificial sea water for the purpose, but most workers have eventually found it necessary to add either natural sea water or earth extract in small quantities before satisfactory algal production is realized. Suitably enriched artificial sea water may prove satisfactory and less expensive for laboratories removed from the sea, and annotated formulae for some of these are given by Galtsoff (1937).

Natural sea water is simple to use and yields good results in the culture of most Foraminifera. The water should be filtered and then stored for several weeks in the dark at a cool temperature to reduce algal and bacterial growth. It is generally not necessary to filter the water through excessively fine filters—an exasperating chore—but a reasonable effort should be

made to eliminate most megascopically visible particulate matter before the water is set aside for ageing. As a general rule it is probably a safe practice to obtain sea water from an area free of pollution, but some species are not very particular about their environment.

Føyn's (1934) "Erdscheriber" has given highly satisfactory results in the author's cultures. The formula, a modification of an earlier one devised by Schreiber (1927), is as follows:

Earth extract	50.00 c.c.
$NaNO_3$	0.10 gms.
$Na_2HPO_4 \cdot 12H_2O$	0.02 gms.
"Aged" sea water	1000.00 c.c.

The earth extract is prepared by autoclaving one kilogram of humus-rich garden soil in a liter of glass-distilled water for one hour and allowing it to settle for several days until a clear or straw-colored fluid can be decanted from the sediment. Sterile technique is generally desirable, although not essential, and the extract should be stored under refrigeration to prevent bacterial growth. After the addition of the extract and salts to the sea water the medium is ready for use or refrigerated storage.

Culture methods of the future may rely on semi-solid and synthetic media, and preliminary experiments with nutrient agar plates, prepared according to the formula known as "medium 2218" (Zobell and Upham, 1944), have indicated the feasibility of utilizing such media in the culture of *Allogromia laticollaris*. It does seem desirable, in view of the numerous advantages of semi-solid and synthetic media, to develop simple methods involving the use of these in the culture of Foraminifera.

OTHER CULTURE FACTORS

Temperature.—The most logical requirement for the culture temperature is that it approximate that of the natural environment as closely as possible; but experimental studies have shown that a species frequently has a temperature optimum which differs from that encountered at the collecting locality, so that it then becomes possible to maintain higher rates of growth and reproduction in cultures than were realized in nature. A miliolid from Panama City, Florida, for example, has been found to have a temperature optimum in the vicinity of 14°C. in laboratory cultures, although it lives at much higher temperatures in nature. If a collection contains several species it is quite likely that some will dominate cultures kept at one temperature while others will dominate when different temperatures are employed. These relationships can only be determined by experimentation.

The temperature has a marked effect upon the algal population within a culture, and both quantitative and qualitative changes in the composition of mixed algal populations will almost inevitably follow shifts in temperature. If a single species of unicellular alga is present as a food source for a single foraminiferan species the problem is simplified, but as soon as additional plant and animal species are added the problem of temperature requirements is complicated. As a general rule it is best to maintain diatom cultures at approximately 15°C., but some species thrive at the higher temperatures required for the most efficient maintenance of warm-water Foraminifera.

The life of a given culture is increased by lowering the temperature, and cultures which are to be stored for prolonged periods without periodic sub-culturing should be kept at reduced temperatures; the reduction should not be so severe, however, as to kill the food algae or Foraminifera. Species which the author has kept in high productivity at room temperature may be maintained in a state of reduced activity at a temperature of 15°C. without deleterious results. At the reduced temperature the culture medium is exhausted less rapidly and the warm-water foraminiferan species reproduce less often, thereby lengthening the life of the entire culture. If high productivity is desired any given species should be maintained at the upper end of its optimal temperature range, a point determined only by experimentation.

Salinity.—An attempt should be made to duplicate the salinity of the natural environment when establishing laboratory cultures, but experimentation has shown that many species have such wide salinity tolerances that the factor becomes of little practical im-

portance in such studies. It may be that some species have restricted salinity tolerances, but a critical investigation of these has not yet been conducted. Most students of foraminiferal culture methods have found it satisfactory merely to replace evaporated water with an equivalent volume of distilled water, but the writer has found it more economical simply to replace cultures showing marked evaporation with freshly prepared ones. It is possible to remove most of the fluid from a culture and replace it with fresh medium without disturbing the Foraminifera, a method which is particularly useful in the culture of larger species.

Light.—The direct influence of this factor upon Foraminifera is practically unknown, but it seems doubtful that light of the intensities required by suitable food algae plays a direct role in regulating foraminiferal activity. The quality and quantity of light are important for adequate algal growth, however, and as such are of primary importance to foraminiferal productivity.

Both incandescent and fluorescent lamps have proven as effective in the author's laboratory as natural daylight. A suitable intensity for several species which have been so maintained is from 5 to 20 foot-candles. If this intensity is increased to 25 foot-candles algal growth deteriorates seriously after two or three weeks, but if the optimum range is maintained the cultures continue for several months without exhaustion. If cultures are to be kept in a state of reduced activity the illumination can be reduced to the 5 foot-candle level or even lower without harmful effects, but if high productivity is to be maintained more intense illumination is required.

So little is known concerning the effect of other physico-chemical factors on foraminiferal growth and reproduction that no significant statement can be made about these at present.

Associated organisms.—Cultures started from marine collections will eventually be found to contain an assortment of bacterial and protozoan associates in addition to the Foraminifera and algae. As a general rule such small organisms cause no apparent trouble in cultures and no student of the Foraminifera has deemed it necessary to attempt to remove them. Before precise studies on nutritional requirements can be undertaken it will be necessary to prepare cultures which contain no other living organism than the desired foraminiferan and possibly a single species of alga, but for many purposes mixed populations are not objectionable. The destructive role of copepods has been mentioned previously, as has the unfortunate chain of events resulting from excessive growth of filamentous algae. Few controlled observations on the direct influence of other associated organisms on the Foraminifera have been made, but in most cases the novice should encounter little difficulty beyond those mentioned above.

ROUTINE CULTURE PROCEDURES

Inoculating.—Before the Foraminifera are inoculated into a culture it is desirable to obtain a thin growth of healthy diatoms or other suitable unicellular algae in the culture dish. If the fluid medium has been supporting algae for more than two or three weeks it is generally advisable to replace it with fresh medium before introducing the Foraminifera. Should it prove impossible to prepare the algal substratum before the Foraminifera are added, it is possible to add algae and Foraminifera simultaneously and obtain successful cultures. Should excessive algal growth occur before the Foraminifera are added the algae should be distributed into additional dishes.

The number of Foraminifera added to a culture varies with the purpose for which the culture is to be used, the size of the dish, the size of the foraminiferan, the life span of the species and a number of other factors. In general, however, two dozen specimens of a species which averages 400 to 500 microns in diameter should be adequate for a 4-inch finger bowl, while 50 to 150 specimens of a small species usually give good productivity within a reasonable time. The amount of water, detritus and other organic matter should be minimized in making the transfer; for this purpose it is usually best to isolate the desired number of Foraminifera in a small dish and then remove any undesirable materials by pipette until the Foraminifera are concentrated within a small vol-

ume of clean sea water or nutrient medium. They are then ready to be pipetted into the culture dish and set aside to develop.

The specimens should be handled carefully by mouth pipette to prevent undue mutilation. If possible a specimen should be induced to withdraw its pseudopodia by gentle prodding before it is removed from the substratum. In this way the pseudopodia are not ruptured and the specimen can be removed without excessive shock. Many species, *Allogromia laticollaris*, for example, are not unduly sensitive to the loss of portions of their pseudopodia and can be treated rather mercilessly during the transfer process.

Isolation cultures are inoculated by pipetting a single, well-cleaned specimen (a pipette and finely-trimmed sable-hair brush are useful in the cleaning operation) from a larger culture into an isolation dish which has a clean, thin growth of algae. The progeny of isolated specimens may be allowed to continue multiplication for a few generations in the isolation dish, but eventually they should be removed and inoculated into a more commodious container. Such known-lineage cultures then become valuable in the study of infra-specific variation.

A wise insurance investment against possible loss of established cultures is the maintenance of a set of stock cultures from which the working cultures can be derived. As soon as a few develop adequate growths of desired species they should be set aside in a safe storage place, periodically examined and kept in a suitable condition for sub-culturing.

Sub-culturing.—In the closed system of laboratory cultures each culture passes through a youthful, mature and senescent period, so that it becomes eventually necessary to rejuvenate the culture in order to restore the productivity of the foraminiferal population. The nutrient materials in the water are gradually exhausted and the waste products of organic metabolism accumulate to inhibit further growth and reproduction. During its youthful period the rate of growth and reproduction of the foraminiferal population increases rapidly until relatively stable maturity is attained. During the mature period the level of reproduction and the rate of growth are fairly uniform, although both are lower than they were during the youthful stage. With the onset of old age, however, the cultures show little or no growth and reproduction, although the individual Foraminifera may continue to feed and move about slightly. An old culture can be stored at a reduced temperature and maintained in a viable condition for many months, and, as a reserve stock, is useful in this state of reduced animation; if high productivity is required the Foraminifera must be removed to fresh cultures.

The active, productive life of a culture is short in comparison to its absolute longevity, and the length of each period varies with the species and its organic and inorganic environment. The reproductive span of a species should be determined before extensive sub-culturing begins, since it is a simple matter to sub-culture a species so frequently that it cannot maintain itself. There appears to be a minimum population size below which the species cannot readily maintain itself, and it is this number which serves as an important clue to suitable sub-culturing periodicity.

It is possible to sub-culture most species by simply pipetting a few individuals to a dish of fresh medium and algal substratum. Some smaller forms, such as *Allogromia laticollaris* and *Spiroloculina hyalina*, are more easily transferred by macerating a small patch of Foraminifera-laden algae in a dish of fresh medium, since the algae reproduce rapidly enough to provide adequate sources of food without prior preparation of the substrate, and the transfer method is faster than the more laborious pipetting procedure.

As an example of the sub-culturing period, the former species should be sub-cultured every three or four weeks (when grown at 24°C.) if maximum productivity is required for a sustained period.

Examination.—A low power stereoscopic microscope is most useful in the examination of mass as well as isolation cultures. With the 4X objective and 12.5X ocular of such an instrument it is possible to determine the general condition of small specimens, and with the lower magnifications the condition of the culture as a whole. The

higher magnifications afforded by the compound microscope are generally required for the detailed examination of individual specimens, and a water-immersion objective is particularly useful in examining specimens in isolation culture.

Isolation culture dishes of the type described earlier can be so mounted as to facilitate examination with either microscope, but highly active species, such as *Allogromia laticollaris*, crawl up the side of the dishes, making examination extremely difficult unless a tilting examination stage is constructed for the purpose. Some workers, notably Myers, have found a horizontal microscope most useful in the study of specimens in mass cultures.

Harvesting.—The removal of large specimens by means of a bulb- or mouth-pipette is a simple matter, but if large quantities of specimens are to be harvested a procedure similar to that employed in panning gold or other heavy minerals is more useful. The nature of the algal substratum and of the attachment of the Foraminifera to this substratum determines the harvesting method that should be used, of course, but if a firm diatom mat on a filamentous framework has been forced to develop in the cultures the panning procedure generally works wonders in concentrating the Foraminifera.

The writer hopes that this discussion of the very simple methods used in the culture of Foraminifera will stimulate other students of the group to begin the study of these animals in laboratory cultures.

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MOLLUSKS FROM THE COGOLLO AND LA LUNA FORMATIONS (CRETACEOUS) OF THE CHEJENDÉ AREA, WESTERN VENEZUELA

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ABSTRACT—A collection of mollusks from the Cogollo formation and the middle part of the La Luna formation of the Chejendé area, western Venezuela, has been studied.

Neithea (*Neitheops*) cf. *N.* (*N.*) *occidentalis*, *Lopha scyphax*, and *Liopistha* cf. *L. cornueliana* have been identified from samples of the Cogollo formation while *Inoceramus* (*Mytiloides*) *labiatus*, *Inoceramus striatoconcentricus* and *Didymotis variabilis* have been found in the samples from the La Luna formation. These determinations seem to indicate an upper Albian or lower Cenomanian age for the Cogollo formation and a Turonian age for the middle part of the La Luna formation in the Chejendé area.

INTRODUCTION

IN 1946, A. Salvador and M. F. Nero, in the course of stratigraphic field work in the Chejendé area in the northeastern part of the State of Trujillo, western Venezuela, collected a number of samples from the Cretaceous Cogollo and La Luna formations. The mollusks from these samples were submitted to R. F. Rutsch for study. This paper covers a few brief considerations on the stratigraphy of the Cogollo and La Luna formations in the Chejendé area, and the description of their molluscan faunas. It is published with the permission of the Mene Grande Oil Company and the Gulf Oil Corporation.

LOCATION OF SAMPLES

The Chejendé area is situated in the northeastern part of the State of Trujillo. The area lies in the northern flank of the Merida Andes, in the region where this range of mountains dies out toward the northeast and plunges under the Carora and Barquisimeto plains.

Figure 1 shows in its upper part the location of the Chejendé area. The lower part shows the geographic situation of the studied samples within the Chejendé area.

The exact stratigraphic position of some of the samples is well known as they were collected in connection with the measurement of detailed stratigraphic sections. They are shown in figure 2. The stratigraphic position of some of the other samples is known only approximately. It is indicated in the following list together with the locality description of the samples. Sample numbers refer to the collections of the Mene Grande Oil Company, Caracas, Venezuela.

Sample A-7544. Chejendé-Ranchería road, just south of the town of Ranchería. La Luna formation. Middle part of the formation.

Sample A-8608. Loose boulders near Chejendé-Ranchería road, about 1 km. east of Chejendé. La Luna formation. Stratigraphic position not known.

Samples A-7562, A-8841, A-8858, A-8859, A-8862, A-8864, A-8868 and A-8870. Detailed stratigraphic section along the Chejendé-Mitón road. For stratigraphic position see figure 2.

Samples A-9253 and A-9260. Detailed stratigraphic section near the small settlement of La Ceiba. For stratigraphic position see figure 2.

Sample A-9722. Trail along the top of the ridge of La Loma, 3 kms. southwest of Casa de Zinc. La Luna formation. Middle part of the formation.

Sample A-9750. 500 mts. southeast of Valle Hondo on a small trail to the Carache River. La Luna formation. Middle part of the formation.

Samples A-9775 and A-9776. Small trail branching from the Chejendé-Mitón road at the small settlement of Las Lajas. Cogollo formation. Thick, massive bed of bluish-gray, coarsely crystalline, very

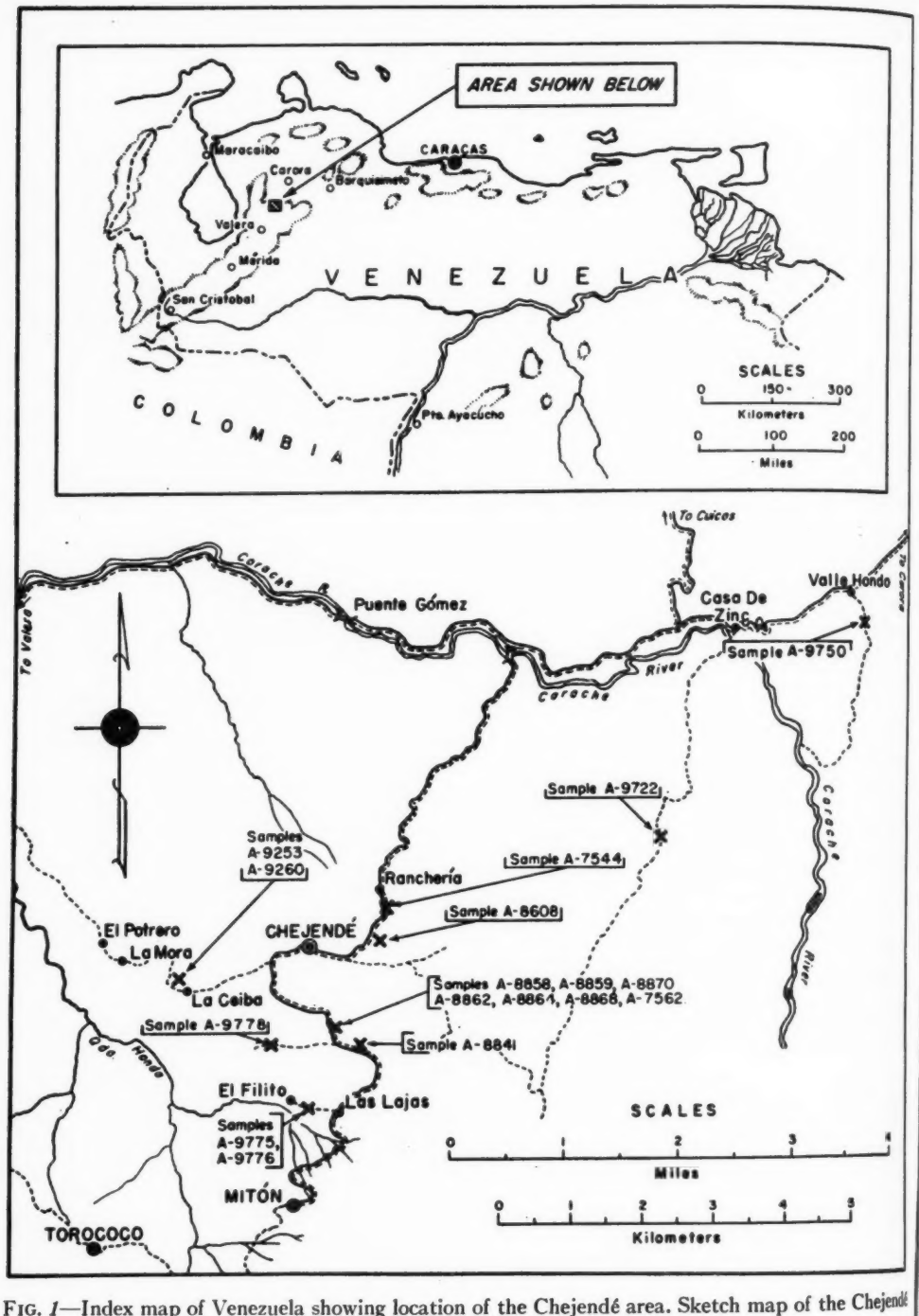

FIG. *1*—Index map of Venezuela showing location of the Chejendé area. Sketch map of the Chejendé area showing location of samples.

fossiliferous limestone. Probably equivalent to bed of sample A-8841 in Chejendé-Mitón road section.

Sample A-9778. Ridge between Quebrada Los Timbetes and Quebrada Tiguagüis, 1.5 kms. south of Chejendé. La Luna formation. Approximately upper third of the formation.

STRATIGRAPHY

The Cogollo and La Luna formations are well-defined lithologic units which have been recognized for many years in western Venezuela by most geologists. References to them in the literature are abundant.

In the State of Trujillo, and specifically in the Chejendé area, these formations are well exposed and a number of detailed stratigraphic sections have been measured on them. Figure 2 shows parts of some of these sections and the stratigraphic position of some of the samples described in this paper.

The Cogollo formation is typically composed of bluish-gray, massive, hard coarsely crystalline limestones, locally very fossiliferous. It grades into the underlying predominantly sandy Uribante formation through a series of massive beds of hard, sandy limestones and calcareous sandstones separated by layers of softer sandy shales and calcareous shales. These beds have been generally considered as the base of the Cogollo formation. The Cogollo formation, which is several hundred meters thick on the western side of the Maracaibo Lake Basin, has in the State of Trujillo a very reduced thickness. In the Chejendé area it varies from 15 to 50 or 60 meters, most commonly from 30 to 35 meters. The age of the formation based on the study of ammonites collected in the Chejendé area is from middle Albian to lower Cenomanian. In the Chejendé area the Cogollo formation grades upward into the La Luna formation through a zone where the bluish-gray, massive limestones of the "Cogollo type" are found interbedded with the dark gray to black limestones and calcareous shales of the "La Luna type." This zone of transition is quite variable in thickness, and has been arbitrarily included in the Cogollo formation.

The La Luna formation is typically composed of dark gray to black, hard, calcareous shales, and black or dark gray limestones in beds of variable thickness. The formation is bituminous throughout and contains typical ellipsoidal limestone concretions of varying size. In the Chejendé area the calcareous shales form the bulk of the formation. The La Luna formation maintains a fairly constant thickness of about 100 to 130 meters in the State of Trujillo. Based on the study of the ammonites and Foraminifera collected in the Chejendé area the formation seems to have an age ranging from lower Cenomanian to lower Santonian.

The La Luna formation is overlain by the shales of the Colón formation. The base of the Colón is marked in the Chejendé area by a very characteristic horizon composed of 2 to 4 meters of light gray to brown, buff or yellowish, very light and porous shale containing abundant plant remains, fish scales, fragments of fish bones, and some glauconite. This horizon has been recognized all over western Venezuela and generally marks the base of the Colón formation.

SYSTEMATICS

Genus INOCERAMUS Sowerby, 1814[1]

Subgenus MYTILOIDES Brongniart, 1822

INOCERAMUS (MYTILOIDES) LABIATUS (Schlotheim) sensu lato

Plate 40, figure 1

The following is a selected bibliography of the South American representatives of *Inoceramus labiatus* sensu lato.

?Inoceramus labiatus (Schlotheim) BRÜGGEN, 1910, Neues Jahrb. Beilage Bd. 30, p. 750 (=*I. striatoconcentricus* according to Heinz); MAURY, 1912, Contr. Paleont. Trinidad, p. 41, pl. 7, figs. 7, 8 (attribution to *I. labiatus* questionable); MAURY, 1936, Cretaceo de Sergipe, p. 111, pl. 8, fig. 14 (fragmentary specimen); GERTH, 1941, Geol. Südamerikas, pp. 346, 349, 359, 365, 588; LISSON, 1942, Fósiles Peruanos, p. 111.

Inoceramus labiatus? (Schlotheim) DIETRICH, 1934, Estudios geol. y pal. Cordillera Oriental de Colombia, p. 84.

Inoceramus labiatus (Schlotheim) DIETRICH, 1924, Centralbl. Min. etc., p. 186; REESIDE (in Wasson and Sinclair), 1927, Bull. Am. Assoc. Petroleum Geologists, vol. 11, p. 1278, pl. 10, figs. 1, 7; HEINZ, 1928, Hamburg min.-geol. Staatsinst. Mitt., 10, pp. 47, 48, 54, 55, 61, 68, 69, 85, 86, 88, 90, 91, 93; SCHUCHERT, 1935, Hist. Geol. Antillean-Caribbean Region, pp. 160, 174, 179–182, 192, 302, 688; STEPHENSON (in Hedberg and Sass), 1937, Bol. Geol.

[1] See Stephenson, 1947, pp. 172–173.

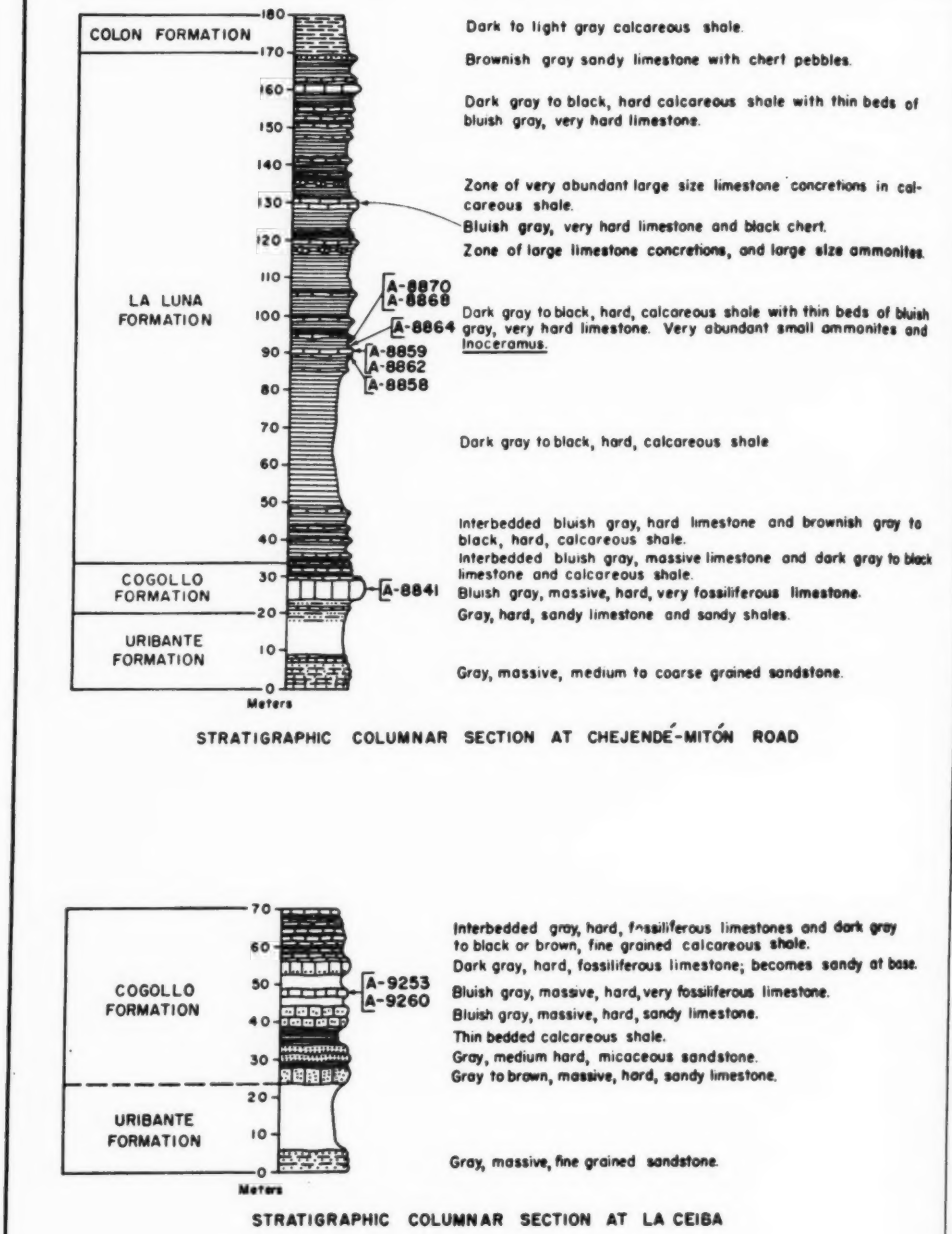

FIG. 2—Stratigraphic columnar sections, Chejendé area, showing location of samples.

Min. Venezuela, t. 1, p. 85; HEDBERG, 1937, Bull. Geol. Soc. America, vol. 48, p. 1991; RENZ, 1942, Strat. northern South America, Trinidad and Barbados, p. 525; IMLAY (in Hedberg and Pyre), 1944, Bull. Am. Assoc. Petroleum Geologists, vol. 28, p. 11; LIDDLE, 1946, Geol. Venezuela and Trinidad, pp. 232, 241, 244; TSCHOPP, 1948, Geol. Skizze von Ekuador, p. 24.

Inoceramus labiatus has a nearly worldwide geographical distribution and is a very variable species. Unfortunately our knowledge of the numerous subspecies and their nomenclature is in a confused state. The studies made by Heinz, Seitz, Maury and others, though adding new information, show that a revision based on the holotypes is absolutely necessary. The holotype of *I. labiatus* s.s., for instance, is only known by the figure published in Knorr and Walch.

We have in our collection from the Chejendé area several well-preserved specimens of *Inoceramus* (*Mytiloides*) *labiatus* s.l.

They are related with the form figured by Woods (1899–1913) as *Inoceramus labiatus* in plate 50, fig. 1, of his monograph of the Cretaceous Lamellibranchia of England. An even more closely related form has been described by Seitz (1934) as "*Inoceramus labiatus* var. *opalensis* Böse n.f. *elongata*" a name which from a nomenclatural standpoint is not acceptable.

Localities.—A-7544, A-8608, A-8858, A-8859, A-8862, A-8864, A-8868, A-8870, A-9722, A-9750.

Stratigraphic significance.—*Inoceramus* (*Mytiloides*) *labiatus* is one of the important markers of the European lower Turonian (*labiatus* zone). According to Seitz (1934) the subspecies "*elongata*" which is very closely related with our Venezuelan form occurs in the same stratigraphic unit.

Inoceramus labiatus occurs in the Turonian of North Africa (Pervinquière, 1912) and Madagascar (Heinz, 1928), and is quoted by Stoliczka (1870–71) from India.

In North America *I. labiatus* is described from the Benton formation (Turonian) of the western interior (Hansen, 1929, p. 86) and from the Eagle Ford (Turonian) of Mexico (Boese, Boese and Cavins, Burckhardt a.o.) and Texas.

Maury (1912) was evidently the first author who described "*Inoceramus labiatus*" from Venezuela. The specimens which were also studied by T. W. Stanton originate from "probably Upper Cretaceous" beds of the "ravines on the right and left sides of the trail from Guanoco to Hurupu, on the hillside just above the stream called Rio Colorado." The specimens figured by Maury differ from our representatives of the La Luna formation by larger, less mytiliform shape and weaker, less regular concentric undulations. The determination of these specimens from the "Guanoco-Hurupu" trail as *I. labiatus* seems questionable.

Later Dietrich (1924) quotes *Inoceramus labiatus* from the "Turonian" of Cantaro on the lagoon of Unare, and Heinz (1928, pp. 48, 61) from Barbacoas near Tocuyo. According to Maury (1936) the species also occurs at "Periquito, Cumanocoa, San Augustin, Guachero and other localities."

Hedberg and Sass (1937) mention *I. labiatus* (determination by L. W. Stephenson) from the La Luna formation and Hedberg and Pyre (1944) from the Querecual formation of Anzoategui (determination by Imlay).

Inoceramus labiatus is also quoted from the Turonian of Ecuador (Reeside, in Wasson and Sinclair, Gerth, Tschopp) and questionably from the Turonian of Sergipe in Brazil (Maury, 1936).

Whether or not the determination of Brüggen (1910, p. 750, also quoted in Gerth and Lisson) is correct cannot be decided without figures. According to Heinz the specimens of Brüggen belong rather to *Inoceramus striatoconcentricus* Gümbel, also of Turonian age.

We may conclude that the Turonian (probably lower Turonian) age of Localities A-7544, A-8608, A-8858, A-8859, A-8862, A-8864, A-8868, A-8870, A-9722 and A-9750 is highly probable.

INOCERAMUS STRIATOCONCENTRICUS? Gümbel

Inoceramus striato-concentricus GÜMBEL, 1868, Geognost. Beschr. ostbayr. Grenzgeb., p. 766; GÜMBEL, 1886, Verz. Regensburg, p. 69, pl. 2, fig. 4; HEINZ, 1928, Oberkreide-Inoceramen Südamerikas, p. 68, pl. 4, figs. 3a, 3b.
Inoceramus striatus concentricus Gümbel LIDDLE, 1946, Geol. Venezuela and Trinidad, p. 216.

According to Heinz this species is known from Cuesta de Huanayamba, west of Cajamarca, from Yamaluco between Huam-

bos and Ambo in northern Perú, and from Barbacoas near Tocyuo in Venezuela. Heinz had the collection of Brüggen at hand and states that the form described by Brüggen (1910, p. 750) as *Inoceramus labiatus* belongs (at least partly) to *Inoceramus striatoconcentricus*. Brüggen assumed a Senonian age of his representatives but according to Heinz the age is Turonian. Heinz (1932, p. 20) created the genus *Striatoceramus* with *Inoceramus striatoconcentricus* as type. All these "genera" of Heinz are absolutely unacceptable.

Localities.—A-7562, A-9778.

Stratigraphic significance.—In Europe (Germany, Carpathians, England) this species is restricted to the Turonian and especially to the lower part of the upper Turonian. According to Heinz the same age is also probable in South America. Our specimens from Loc. A-7562 and A-9778 are fragmentary, and the determination and correlation are therefore questionable.

Genus NEITHEA Drouet, 1825
Subgenus NEITHEOPS Stewart, 1930
NEITHEA (NEITHEOPS) cf. N. (N.) OCCIDENTALIS (Conrad)

For synonymy see Stanton (1947, pp. 43–44).

Neithea (*Neitheops*) *occidentalis* belongs to a group of Neitheas which has world-wide distribution. Unfortunately the differences between these species are insufficiently known and several types may later prove to belong to the same species.

Our Venezuelan representatives are fragments only but seem to agree perfectly well with the typical *N. occidentalis*. As already stated by Stanton, *Neithea* (*Neitheops*) *irregularis* Böse from Mexico is evidently identical with *Neithea occidentalis*.

N. occidentalis is closely related with the following species:

Neithea (*Neitheops*) *syriaca* (Conrad) from the Aptian of the Republic of Lebanon (see Vokes, 1946, p. 166, pl. 4, figs. 1–7). *N. syriaca* seems to differ from *N. occidentalis* by the ornamentation of the left valve but otherwise the two types are very similar. Comparison of type material will have to prove whether the American and Lebanese forms are identical.

Neithea (*Neitheops*) *quinquecostata* (Sowerby) and *Neithea* (*N.*) *morrisi* (Pictet and Renevier) are closely related but the typical specimens figured by Woods (1899–1913, p. 202) and Pictet and Renevier (1854–1858) clearly differ from our Venezuelan species. *N. quinquecostata, and N. morrisi* are quoted from the Cretaceous of Perú (Lisson, Steinmann, Sommermeier, Neumann), Ecuador (Reeside, Gerth) and Jamaica (Schuchert). Probably some of these specimens may belong to *N. occidentalis* rather than to *N. quinquecostata* or *N. morrisi*. For instance, the specimens figured by Steinmann (1929, p. 125, fig. 139) from Perú, by Reeside (1927, p. 1278, pl. 10, figs. 9 and 10) from Ecuador and by Knechtel, Richard and Rathbun (1947, p. 56, pl. 7, figs. 2 and 3) from Perú seem very similar to *N. occidentalis* and should be compared with this species.

Neithea (*Neitheops*) *shawi* Pervinquière (1912, p. 136, pl. 9, figs. 1–6) which according to E. Basse, (1928, p. 123) occurs in the Cenomanian of Perú clearly differs from our Venezuelan specimens.

Localities.—A-8841, A-9775.

Stratigraphic significance.—According to Stanton *Neithea* (*Neitheops*) *occidentalis* is a common and widely distributed type in the Fredericksburg group, especially in the Comanche Peak limestone. The Fredericksburg group is the equivalent of the middle Albian. It also occurs in the Walnut clay and the Edwards limestone (middle Albian) but also ranges both below and above the limits of the Fredericksburg group (Quitman formation = middle Albian; Glen Rose limestone = middle Albian; Purgatoire formation = middle-upper Albian; Kiowa shale = middle Albian).

Genus LOPHA (Bolten) Roeding, 1798
LOPHA SCYPHAX (Coquand)
Plate 40, figures 4, 5

Ostrea scyphax COQUAND, 1854, Descr. geol. Province de Constantine, p. 143, pl. 4, figs. 1-4.
Ostrea Syphax COQUAND, 1869, Monogr. Genre Ostrea, p. 138, pl. 55, fig. 13, pl. 56, figs. 1-5, pl. 58.
Alectryonia Syphax (Coquand) PERVINQUIÈRE, 1912, Etudes Paleont. Tunisienne, p. 203, pl. 14, figs. 15–18 with bibliography.
?Ostrea Syphax Coquand SCHLAGINTWEIT, 1912, Neues Jahrb. f. Min. etc. Beil. Bd. 33, 1912, pp. 56, 58, 60, 61, 65, 90, pl. 5, figs. 1–3.

?Alectryonia syphax (Coquand) EUGSTER, 1922, Geol. Columbian. Ostkordilleren, p. 254.
?Ostrea syphax Coquand REESIDE (in Wasson and Sinclair) 1927, Bull. Amer. Assoc. Petroleum Geologists, vol. 11, p. 1272, pl. 13, figs. 13, 14.
?Ostrea (Lopha) syphax cf. Coquand DIETRICH, 1934, Lam. Cret. Cordillera Oriental, p. 86.
?Lopha syphax (Coquand) MAURY, 1936, Cretaceo de Sergipe, p. 159. Identification questionable.
?Ostrea Syphax Coquand LISSON, 1942, Fósiles Peruanos, p. 101, 102, 103.

There are several partly well-preserved specimens of this species available for study which agree with the figures published by Coquand and Pervinquière.

Lopha subovata (Shumard) (see Stanton, 1947, p. 24 = *Ostrea marcoui* Boese) is a quite different species and is certainly not related to *L. scyphax*.

Localities.—A-8841, A-9253, A-9260, A-9775.

Stratigraphic significance.—In North Africa and Europe (southern Italy and Sicily) *Lopha scyphax* is characteristic of the Cenomanian and is most common in the lower part of this stage.

In South America, *Lopha scyphax* is mentioned from Perú, Colombia, Ecuador, Brazil and Venezuela. However, the specimens from Perú described by Schlagintweit are probably not identical with the typical *L. scyphax*. The Peruvian form is more rectangular and the ribs seem less regular and less sharp. These specimens originate from beds which, according to Schlagintweit (1912), belong to the Vraconian. From Colombia, *Lopha scyphax* is mentioned by Eugster and by Dietrich, but no figures are published. The age is given as Cenomanian. From Ecuador, *Lopha scyphax* is quoted by Reeside, but the identification with Coquand's type is somewhat questionable. The age of the Ecuadorian specimens is given as Albian. The representatives from the Turonian of Brazil are in a bad state of preservation and probably not identical with the typical *L. scyphax* ("member of the *syphax-dichotoma* group," Maury, 1936). From Venezuela, *Lopha scyphax* has been reported by Schlagintweit (1912, p. 91) from the following localities: "St. Ana bei Carache" and "Umgebung von Barbacoas." These localities are assigned to the Vraconian.

Lopha scyphax in North Africa and southern Europe is evidently characteristic of the Cenomanian. If we disregard the representatives from Brazil, the identification of which is highly questionable, *Lopha scyphax* is represented in South America in the Cenomanian and probably also in the Albian. It is important to state that the specimens described by Schlagintweit originate from beds which he considers as "Vraconian." If we place the Vraconian with the Albian, *L. scyphax* seems also to be represented in this stage, but if we place it with the Cenomanian, these specimens are of Cenomanian age.

In summarizing, we may say that *L. scyphax* suggests the Cenomanian but does not fully exclude the Albian age.

Genus DIDYMOTIS Gerhardt, 1897
DIDYMOTIS VARIABILIS Gerhardt
Plate 40, figure 2

Didymotis variabilis GERHARDT, 1897, Beitr. z.K.d. Kreideformation in Colombien, p. 178, pl. 5, figs. 3a–c; SOMMERMEIER, 1918, Fossilfund a.d. unt. Kreide v. Trinidad, pp. 131, 134, 135, 136; GILLET, 1924, Lamellibranches neocomiens, p. 76; HARRIS (in Waring), 1926, Geol. Trinidad, pp. 92, 94, 96, pl. 16, fig. 4; SCHUCHERT, 1935, Hist. Geol. Antillean-Caribbean Region, pp. 668, 703; GERTH, 1935, Geol. Südamerikas, p. 355.
?Didymotis trinidadensis Sommermeier aff. *D. variabilis* Gerhardt. LIDDLE, 1946, Geol. Venezuela and Trinidad, p. 231.

Through the kindness of Dr. S. Gillet of Strasbourg two specimens of *Didymotis variabilis* from the Hettner and Strübel collections have been made available. They represent the type material of Gerhardt. So far no holotype of *Didymotis variabilis* seems to have been designated. We, therefore, designate the specimen figured on plate 5, fig. 3a, of Gerhardt's publication as holotype. This specimen originates from the "Aptian" of Agua Larga, Cundinamarca, Colombia. Our two specimens originate from "Cerro Pelado, Colombia" and from "Boyaca, Colombia." Both localities are mentioned in Gerhardt's original publication and our specimens evidently belong to this original material. According to Gerhardt the specimens from "Cerro Pelado" were not found in situ but originate from a block in a river bed.

Our Venezuelan collection contains several specimens which evidently are identical with *Didymotis variabilis*.

One specimen from Locality A-8608 is very large and has seven large ribs in the central part of the shell disc. Gerhardt mentions an anterior and posterior ear but neither our specimens from Colombia nor our Venezuelan representatives show these ears.

Didymotis variabilis differs by the shape of the ribs from *D. trinidadensis* Sommermeier (1918, p. 132) from Trinidad. *D. trinidadensis* has also been mentioned by Kugler (1923, p. 258), Gillet (1924–25, p. 76), Harris (in Waring, 1926, pp. 92, 94), Schuchert (1935, p. 688), Gerth (1932–35, pp. 343, 350), Renz (1942, pp. 524, 526) and Liddle (1946, pp. 231, 706, 712, 788). Unfortunately no specimens of *D. trinidadensis* are at our disposal but according to Sommermeier, *D. trinidadensis* has numerous (up to 30) bundled radial ribs, whereas *D. variabilis* has fewer (up to 13), large radials which are not bundled. Otherwise the two species seem identical and the question whether or not they really represent two different species should be re-studied. All our Venezuelan specimens have the few, simple radial ribs of *D. variabilis*.

A third species, *Didymotis roemeri* (Karsten) (=*Inoceramus roemeri*, Karsten, 1886, p. 112, pl. 5, fig. 6a, b; see also Sommermeier, 1918, p. 134) seems to differ from *Didymotis variabilis* by much finer and more numerous radial ribs.

Localities.—A-8608, A-9778.

Stratigraphic significance.—*Didymotis variabilis* Gerhardt is known from Colombia, Trinidad and Venezuela.

In Colombia its stratigraphic range is given as Aptian. The same age is given for the occurrences in Trinidad, but this is evidently based on the age determination in Colombia. In Venezuela, Liddle mentions "*Didymotis trinidadensis* Sommermeier aff. *D. variabilis* Gerhardt" from "discoidal limestone masses and associated calcareous shales 850 feet above the base of La Luna formation on Rio La Luna," together with other mollusks which indicate "an age ranging from Upper Albian into Coniacian."

The range of *Didymotis trinidadensis* itself which is very closely related to *D. variabilis* is given as Aptian (?) -Albian-Cenomanian but all these age determinations are not very conclusive.

Didymotis roemeri (Karsten) according to Sommermeier occurs in the Albian of Colombia but is also mentioned from Ecuador (Wolf, 1892, p. 243="*Inoceramus*" *roemeri* Karsten). According to Tschopp (1948, p. 25) these specimens originate from the Callo formation of upper Cenomanian-Turonian age.

Summarizing we may say that neither the relations between the various species of *Didymotis* nor the stratigraphic range of each species is well enough established to allow exact age determinations. *Didymotis variabilis* certainly indicates an age not older than Aptian but does not exclude a younger, even Upper Cretaceous, age.

Genus LIOPISTHA Meek, 1864

LIOPISTHA cf. L. CORNUELIANA (d'Orbigny)

Plate 40, figure 3

Cardium cornuelianum D'ORBIGNY, 1843, Pal. Française, Terr. Crétacés, T. 3, p. 23, pl. 256, figs. 1 and 2.

Pholadomya cornueliana (d'Orbigny) PICTET and RENEVIER, 1855, Aptien Perte du Rhône et des environs de Ste.-Croix, p. 59, pl. 6, fig. 6; WOODS, 1909, Cretaceous Lamellibr. of England, vol. II, part 6, p. 245, pl. 41, figs. 2 and 3.

Liopistha ? cornueliana (d'Orbigny) GILLET, 1921, Barrémien de Wassy, p. 19.

Liopistha cornueliana (d'Orbigny) GILLET, 1924, Lamellibranches néocomiens, p. 151.

Only one specimen (cast) is available and its state of preservation does not allow an exact specific determination.

The genus *Liopistha* is incompletely known and needs revision. The holotype of *L. cornueliana* originates from the Barremain of Wassy (France).

Our Venezuelan type seems closely related with the holotype figured by d'Orbigny. The specimens figured by Pictet and Renevier, and Woods have probably coarser radial ribs than our Venezuelan specimen. For a definite determination specimens of these localities should be compared.

In *Liopistha inflata* Whitfield (see Wade, 1926, p. 76, pl., 24, figs. 7 and 8) from the Upper Cretaceous (Ripley formation) of Coon Creek, Tennessee, which in shape is similar to our Venezuelan type, the radials seem even stronger and broader.

Locality.—A-9776.

Stratigraphic significance.—As a genus

Liophistha ranges from the Barremian to the Maestrichtian. It is widely distributed in Europe, North America and South America. J. B. Reeside (1927, p. 1271, pl. 11, figs. 14 and 15) figures a *Liopistha* n. sp. aff. *L. ligeriensis* d'Orbigny from the "Turonian" of eastern Ecuador. This specimen has certainly nothing to do with *Pholadomya ligeriensis* d'Orbigny and also the age determination is evidently incorrect, since the specimen is associated with *Trigonia* (*Quadratotrigonia*) *hondaana* Lea and therefore very probably of Aptian age. The figured specimen is probably tectonically distorted and is larger than our Venezuelan type but otherwise not unlike it. An exact comparison without specimens from Ecuador is impossible.

A specifically undetermined "*Liopistha ?* sp." is quoted by Kehrer (1938, p. 50) from the Mucupatí series of the Palmarito-Sabaneta-Mucupatí area of southwestern Venezuela. The fossil has been determined by Woodring and an Upper Cretaceous age is attributed to this fauna. Unfortunately no specific determination is given.

Liopistha cornueliana itself is known from the Barremian (holotype of Wassy), Aptian, Albian and Cenomanian.

STRATIGRAPHIC SIGNIFICANCE AND AGE OF THE FOSSILS

The greater part of the described fossils originates from the La Luna formation and especially from its middle part (Loc. A-7544, A-8608, A-8858, A-8859, A-8862, A-8864, A-8868, A-8870, A-9722, A-9750). All these localities contain *Inoceramus* (*Mytiloides*) *labiatus* (Schlotheim) s.l. the marker of the European lower Turonian ("*labiatus* zone"), also known from the Turonian of North Africa, Madagascar, the Benton formation of the western interior of the United States and the Eagle Ford of Mexico and Texas. A Turonian, probably lower Turonian, age of the middle part of the La Luna formation seems very probable. A Turonian age for that part of the La Luna formation (Loc. A-7562, A-9778) is also suggested by *Inoceramus striatoconcentricus?* Gümbel, but the determination of this species is questionable.

The Cogollo formation is represented by Loc. A-8841, A-9253, A-9260, A-9775 and A-9776. The presence of *Neithea* (*Neitheops*) cf. *N.* (*N*). *occidentalis* (Conrad) known from the Fredericksburg group, Quitman formation, Glen Rose limestone, Purgatoire formation and Kiowa shale in the United States suggests a Cenomanian age but does not exclude an Albian age. This species is represented from localities A-8841, A-9253, A-9260, and A-9775.

Based on the study of the mollusks of the Cogollo and La Luna formations in the Chejendé area we may conclude that the middle part of the La Luna formation is of Turonian age, whereas the above-mentioned localities from the Cogollo formation represent either an Albian (possibly upper) or a lower Cenomanian age.

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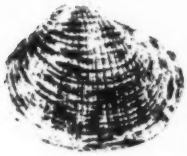
EXPLANATION OF PLATE 40

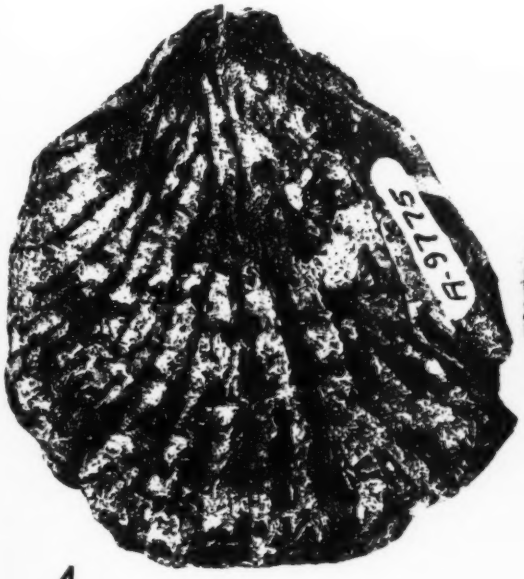
FIG. *1*—*Inoceramus* (*Mytiloides*) *labiatus* (Schlotheim) sensu lato. La Luna formation, Loc. A-8859, ×½. (p. 419)
2—*Didymotis variabilis* (Gerhardt). La Luna formation, Loc. A-8608, ×1. (p. 423)
3—*Liopistha* cf. *L. cornueliana* (d'Orbigny). Cogollo formation, Loc. A-9776, ×1. (p. 424)
4, 5—*Lopha scyphax* (Coquand). Cogollo formation, Loc. A-9775, ×1. (p. 422)

1

2



3



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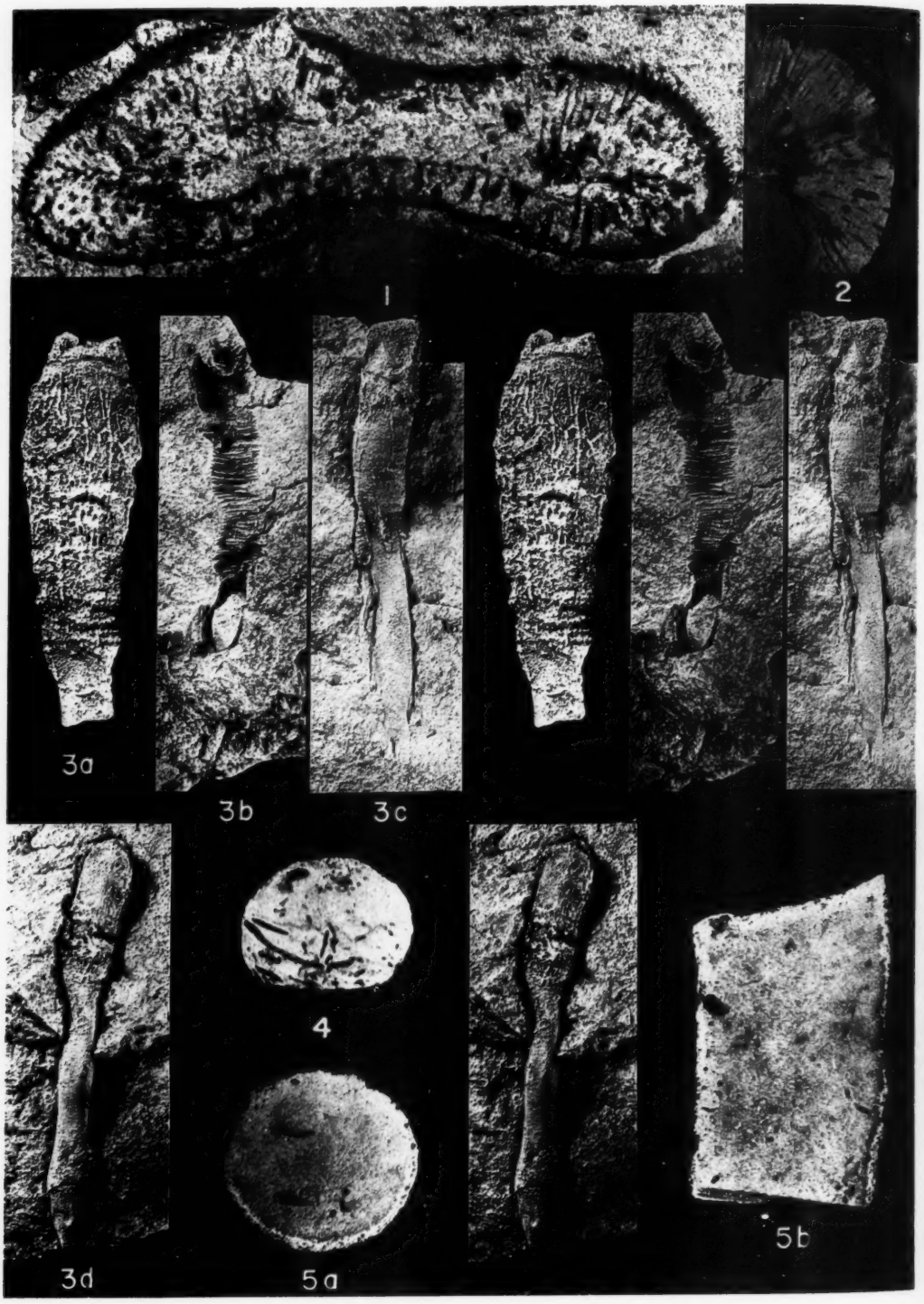
5

Rutsch and Salvador, South American Cretaceous mollusks



Weiss, Middle Ordovician fossils from Minnesota

JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 4, PP. 427–429, PL. 41, 5 TEXT FIGS., JULY 1954

NOTES ON SOME MIDDLE ORDOVICIAN FOSSILS FROM MINNESOTA

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ABSTRACT—*Palaeosynapta flaccida*, a new genus and species of holothurian (?) occurs in the Galena formation (Middle Ordovician) of Minnesota. *Ischadites iowensis* with external spines are present in the same formation. Detailed study of the structure of *Rauffella filosa* Ulrich, described as a sponge, indicates it possibly belongs to the Annelida.

Phylum PORIFERA
Class RECEPTACULITIDA
Genus ISCHADITES Lonsdale, 1839
ISCHADITES IOWENSIS (Owen)
Plate 41, figures 1, 2

Ischadites iowensis (Owen) WINCHELL and SCHUCHERT, 1895, p. 64, pl. F, figs. 5, 6; ROY, 1941, fig. 29 b–e; WILSON, 1948, p. 25, pl. 12, figs. 5, 6, pl. 13, figs. 7, 8.
Ischadites ottawaensis WILSON, 1948, p. 26, pl. 13, figs. 1–4.

Except for the external spines here illustrated, this species has been described frequently elsewhere. Many of the specimens from Fillmore County, Minnesota, are well preserved in microgranular limestone and show superficial spines heretofore unrecorded.

The spines can be seen only in the cross section, are slightly recurved toward the outside lower edge of the body of the specimen, and are 1–2 mm. long. They are somewhat enlarged at their bases, but taper rapidly to slender, sharp points. They appear to be related to the fine rays that taper toward the center of the fossils from the upper and lateral surfaces, and suggest that these rays are really spicule rays instead of canals. Toward the basal periphery of the fossils the spines become shorter, as if their point of disappearance marked the level of the surface upon which the living animal rested. The spines are not present in the basal and lateral parts of the fossil that are penetrated by what may be canals.

Discussion.—A wide variety of shapes and sizes of this species is found in the *Ischadites* zone. Most of the larger ones are more or less crushed and distorted. The original shape was hemispherical with an arch in the middle of the lower surface. *I. ottawaensis*, as figured by Wilson (1948, pl. 13), is merely a flattened *I. iowensis*. If the "side and upper canals" of Wilson are really spicule rays as proposed here, their angle to the bottom would depend upon the degree of crushing

EXPLANATION OF PLATE 41

FIGS. *1, 2*—*Ischadites iowensis* (Owen). *1*, broken-surface cross section of a typical specimen, ×1, U. of Minn. T6710a; *2*, polished section of part of another specimen, oriented as it occurred in the rock, ×2, U. of Minn. T6710b; both from *I. iowensis* zone, Prosser member of Galena formation, Root River Quarry, southwest of the stone arch bridge, SW¼ Sec. 22, T. 102 N., R. 12 W., Fillmore Co., Minnesota. (p. 427)

3a–d—*Palaeosynapta flaccida*, Weiss, n.gen., n. sp. *3a*, stereo-pair of steinkern of upper part showing crystalline network suggesting calcareous bodies, ×2, U. of Minn. T6728a; *3b*, stereo-pair of partial external mold showing wrinkled surface and constriction at top, lower part of tube disappears into matrix, ×1, U. of Minn. T6728b; *3c*, stereo-pair of steinkern of nearly complete specimen, showing flattened base blending into matrix, ×1, U. of Minn. T6728e; *3d*, stereo-pair of steinkern of specimen, complete except for basal tip, ×1, U. of Minn. T6728c; all from the *P. synapta* hypodigm. (p. 429)

4, 5—*Rauffella filosa* Ulrich. *4*, polished cross section, ×2, U. of Minn. T6708b, middle Decorah, Myrah Quarry, SE¼, SW¼ Sec. 12, T. 101 N., R. 7 W., Houston Co., Minn.; *5a*, polished cross section showing bleached edge resulting from weathering, ×2, U. of Minn. T6709b, Decorah formation, Sugar Creek, north edge of NW¼ Sec. 9, T. 103 N., R. 11 W., Fillmore Co., Minn.; *5b*, polished longitudinal section of same specimen from which fig. *5a* was cut, ×2, U. of Minn. T6709a. (p. 428)

of the original biscuit-shaped body. Crushing of the specimen would crowd the rays as they are seen to be in Wilson's figure 1.

There is great similarity between cross sections of the basal part of *I. iowensis* and *Receptaculites oweni* Hall. The idea that these two may be conspecific is not new (for discussion see Roy, 1941, pp. 59–61). However, the largest *I. iowensis* are smaller than the smallest *R. oweni*. No specimens of the latter were seen that retained any sort of upper integument and rays as in the former. Although a few stray *R. oweni* are found in the basal and top parts of the *Ischadites* zone, no instance of the association of the two species in the same bed or closely-spaced beds was observed.

Occurrence.—*Ischadites iowensis* zone in the Prosser member of the Galena formation. The zone occupies an interval of from 20 to 30 feet close to the middle of the formation, and in the middle and upper parts of the Prosser member as restricted by Weiss (1953). The zone lies wholly between the lower and upper *Receptaculites* zones. In the uppermost Stewartville member there is a species of *Ischadites* that is distinctly different from *I. iowensis*, but insufficient material and stratigraphic data are available at this time to warrant description.

Phylum ANNELIDA (?)
Class GEPHYREA (?)
Order SIPUNCULIDA
Genus RAUFFELLA Ulrich, 1889
RAUFFELLA FILOSA Ulrich
Plate 41, figures 4, 5a, b

Rauffella filosa ULRICH, 1889, p. 237, figs. 1, 2, 4; WINCHELL and SCHUCHERT, 1895, p. 75, pl. F, figs. 16–18; SARDESON, 1925, pp. 279–282, pl. 15, fig. 4.

In the original generic description Ulrich (1889, p. 235) described the character of the "inner layer" of the "sponge" in some detail. However, under each of the two described species he stated that the structure of the "inner layer" had not been determined because of poor preservation. The remarks in the generic description appear to be conjecture, although they are stated as fact. His claim that the "inner layer" is spicular is unfounded, both in his own illustrations and in material studied by the writer.

Sardeson (1925) investigated this species in considerable detail. He decisively refuted Ulrich's assignment of the species to the Porifera and concluded that these fossils are the fillings of worm burrows.

Discussion.—This species is included here because photographic illustrations are available for the first time and because a systematic assignment is suggested.

A dozen or so specimens having the characteristic outer surface very well developed were sectioned both transversely and longitudinally and then polished. Study of these sections failed to reveal any structure, either in the interior or the wall, that might suggest a sponge. There is no textural change near the surface that might suggest layering. The light band at the edge in some places is the result of weathering. The species is definitely the lime-mud cast of a sculptured hole, and is fucoidal in nature.

Precise placement of such a form is very difficult, but it is tentatively suggested that it may belong in the order Sipunculida. The external pattern of the species is presumed to have been made by the setae or mouth parts of an annelid worm.

Occurrence.—Locally abundant in the lower middle part of the Decorah formation. *R. palmipes* Ulrich is not known from Fillmore County, Minnesota.

Phylum ECHINODERMATA (?)
Class HOLOTHUROIDEA (?)
Genus PALAEOSYNAPTA Weiss, n. gen.

Remains of fossil animals closely resembling in form and habit the members of the modern family Synaptidae and, in particular, the genus *Synapta*.

Vertical, irregularly subcylindrical, tapering slightly at the top (anteriorly), with compressed lower end. They do not taper uniformly, but are thinner in some places than in others. They are not uniformly cylindrical, being more or less flattened in places. The outer surface is transversely wrinkled, especially so in the upper one-third to one-half of the cylinder. The inner surface shows little pattern, but there are a few irregular, longitudinal wrinkles near the top. The exterior of the internal molds and the spaces between the internal and external molds have irregular networks of crystals

that suggest that the integument included abundant calcareous deposits.

The name derives from the apparent similarity to the genus *Synapta*.

Type species.—*Palaeosynapta flaccida*, n. sp.

PALAEOSYNAPTA FLACCIDA Weiss, n. sp.
Plate 41, figures 3a-d

The principal distinguishing characters have been placed in the generic description pending possible future discovery of other species to show in what ways the species may differ.

The species attains a maximum length of about 10 cm. and maximum diameter of 1 cm. Most adults measure only 6–7 cm. in length, however.

The name derives from the fact that the body shape was modified by the enclosing medium.

Discussion.—The irregular and wrinkled nature of these fossils shows that the organism assumed shapes that conformed to the containing material. Their position in the rock suggests that they lived buried upright in the bottom mud. One specimen was found with the anterior end bent over into the plane of bedding. In the absence of suitable material to demonstrate the presence and type of calcareous bodies, the comparison of this fossil with the holothurian *Synapta* is merely analogy.

Although lacking the structural detail of *Mackenzia costalis* Walcott (1911), *P. flaccida* does not appear to be closely related to that species.

Appreciation is due Dr. A. H. Clark of the U. S. National Museum, who is responsible or the original suggestion that these fossils may be synaptid holothurians (Josiah Bridge, personal communication, 1952).

Occurrence.—*Palaeosynapta flaccida* zone in the upper part of the Stewartville member of the Galena formation. The zone apparently is only about 5 feet thick, but ranges through the upper third of the Stewartville member. The individuals are in places found penetrating or closely associated with stylolites, but are clearly not stylolitic in nature.

Hypodigm.—U. of Minn. T-6728 a–g; seven specimens in four pieces of rock. Collected by C. R. Stauffer from the Stewartville member 38 feet below the top of the Galena formation, at the Lime City Quarry at the bridge over Deer Creek, 3.0 miles north of Spring Valley, Minnesota; NE¼ SE¼ Sec. 9, T. 103 N., R. 13 W.

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A NEW SPECIES OF *ASTRAEOSPONGIA* FROM THE MIDDLE ORDOVICIAN OF NORTHERN ILLINOIS

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ABSTRACT—*Astraeospongia dixonensis* n. sp., based upon eleven isolated octactinellid sponge spicules, occurs in Middle Ordovician rocks of Dixon, Illinois. The genus has previously been known in North America only from the Silurian and Devonian.

INTRODUCTION

ACETIC acid residues of rocks from the Briton member (Mifflin formation) of the Middle Ordovician Platteville group have revealed the presence of separate octactinellid sponge spicules belonging to the genus *Astraeospongia*. The material was collected from a quarry in the vicinity of Dixon, Illinois, from the same formation and area as the large sponge fauna Ulrich and Everett found and described in 1890.

Richardson (1950) has summarized accounts of the occurrence of 13 species of octactinellid sponges assigned to the genus *Astraeospongia* for both Europe and North America. In North America the genus has generally been known to range from Middle Silurian to Middle Devonian although Lowenstam (1948, p. 106) has reported a single spicule from early Silurian Alexandrian strata of Illinois. Roemer (1861, p. 15) described *Astraeospongia patina* from rocks in Germany considered to be either Lower Silurian or Upper Ordovician in age. The presence of octactinellid spicules in the Platteville strata, therefore, extends the lower range of *Astraeospongia* to Middle Ordovician.

STRATIGRAPHY

Templeton and Willman (1952) studied the regional stratigraphy of the Ordovician and have published a preliminary account of their results for northern Illinois. The section within the quarry from which the spicules were obtained is essentially the same as the one they describe (p. 20, fig. 10, stop 2). The rocks of the Briton member consist of blue-gray argillaceous limestone with a fine-grained to lithographic matrix containing many fossils. Due to green shale partings, it weathers into thin irregular, nodular layers the surfaces of which become rust stained. The residues, which range from 6 to 14 per cent for 5 random samples of 100 grams each, contain considerable quantities of green flaky clay, some few quartz grains, pyrite, fine skeletal siliceous material, and silicified fossil remains. Acetic acid residues contain a relatively large amount of calcitic echinoderm fragments, conodonts, chitinozoa, and clear crystalline calcite which is apparently secondary fill and replacement. It is remarkable that the tiny fragile sponge spicules, which are calcitic, remain in the residues.

Megascopically the sponges are associated with many other well-preserved fossils including numerous brachiopods, trilobites, large ostracodes, gastropods, pelecypods, bryozoans, cephalopods and corals. Microscopically there are arenaceous Foraminifera (recovered in HCl but destroyed in acetic acid), scolecodonts, ostracodes, holothuroid sclerites, and miscellaneous fragmental materials.

SYSTEMATICS

Phylum PORIFERA
Class DESMOSPONGIAE
Order OCTACTINELLIDA (after Woods, 1950)
Genus ASTRAEOSPONGIA Roemer, 1860

ASTRAEOSPONGIA DIXONENSIS Gutschick, n. sp.
Figures 1a-b, 2a-k

The form of the sponge is unknown. The species is based upon 11 detached spicules in which the six horizontal rays are well developed; whereas, the rays of the vertical axis may or may not be. The holotype (figs. 1a-b, 2e) has a prominent vertical ray developed on one side of the disc but apparently not on the opposite side. This ray is bent but probably was originally normal to

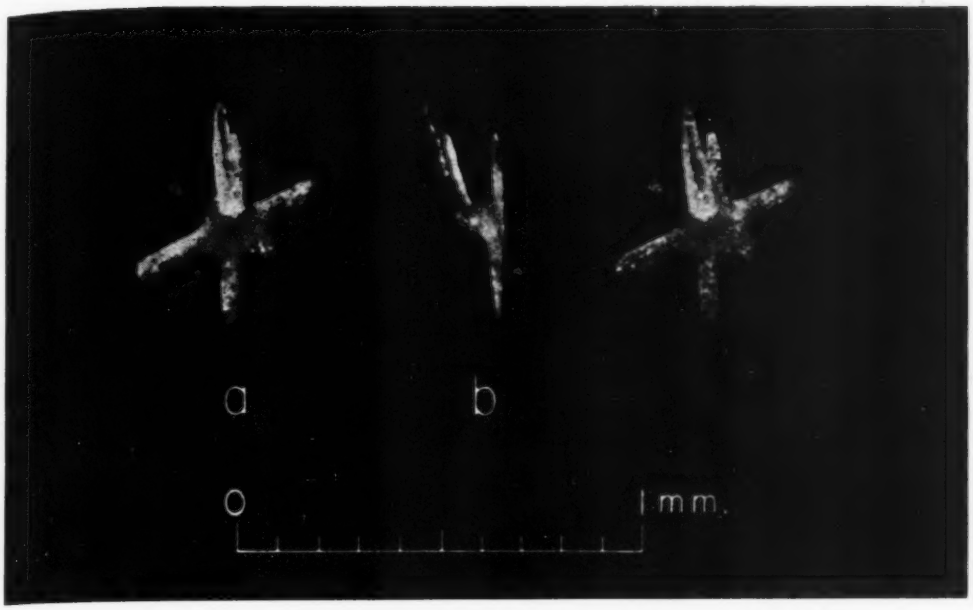

FIG. *1*—*Astraeospongia dixonensis* Gutschick, n. sp. *a*, stereogram of holotype, *b*, side view of holotype.

the plane of the disc and the other six rays. Since the spicules have been obtained from acetic acid residues and necessarily eroded and frayed, statistical parameters have been omitted. One can gain the perspective of proportion by comparing the illustrations with the millimeter scale shown. No spicules have been found which have both vertical rays developed. All spicules are composed of white crystalline calcite which probably replaced the original silica and destroyed the axial canals. No siliceous spicules have been found in any of the residues.

DISCUSSION

Astraeospongia dixonensis is very closely comparable, if not conspecific, with *A. patina* Roemer on the basis of size and shape of spicule. Roemer described the entire fossil sponge with its associated spicules. The enlarged spicule which he illustrates (1861, pl. 3, fig. 5d) appears to have horizontal rays which are slightly petal-shaped with acutely rounded terminations and the vertical rays are reduced to knobs. *A. dixonensis* is slender with subparallel rays and may have a vertical ray.

A. dixonensis differs from Silurian and Devonian species principally in size for the latter forms are generally larger than the Ordovician. The single Middle Silurian Niagaran species *A. meniscus* (Roemer) has spicules whose diameters range from 3 to 7 mm. According to Richardson's tabulation (1950, pp. 84–85), Middle Devonian spicules vary from 1 to 5 mm. often averaging about 2.5 mm. The smaller ones have rays which are either acicular or strong, rounded and club-shaped. This differs appreciably in shape from the rays of *A. dixonensis* as described above.

OCCURRENCE

All specimens were obtained from limestone of the Middle Ordovician (Champlainian) Platteville group, Mifflin formation, Briton member, collected near the center of the N½ Sec. 27, T. 22 N., R. 9 E., in the rock quarry of the Medusa Portland Cement Company about 3 miles northeast of the bridge (U. S. highway 52) over the Rock River, Dixon, Lee County, Illinois (Dixon topographic quadrangle).

Types.—Holotype, USNM No. 123458; paratypes, USNM Nos. 123459a-i.

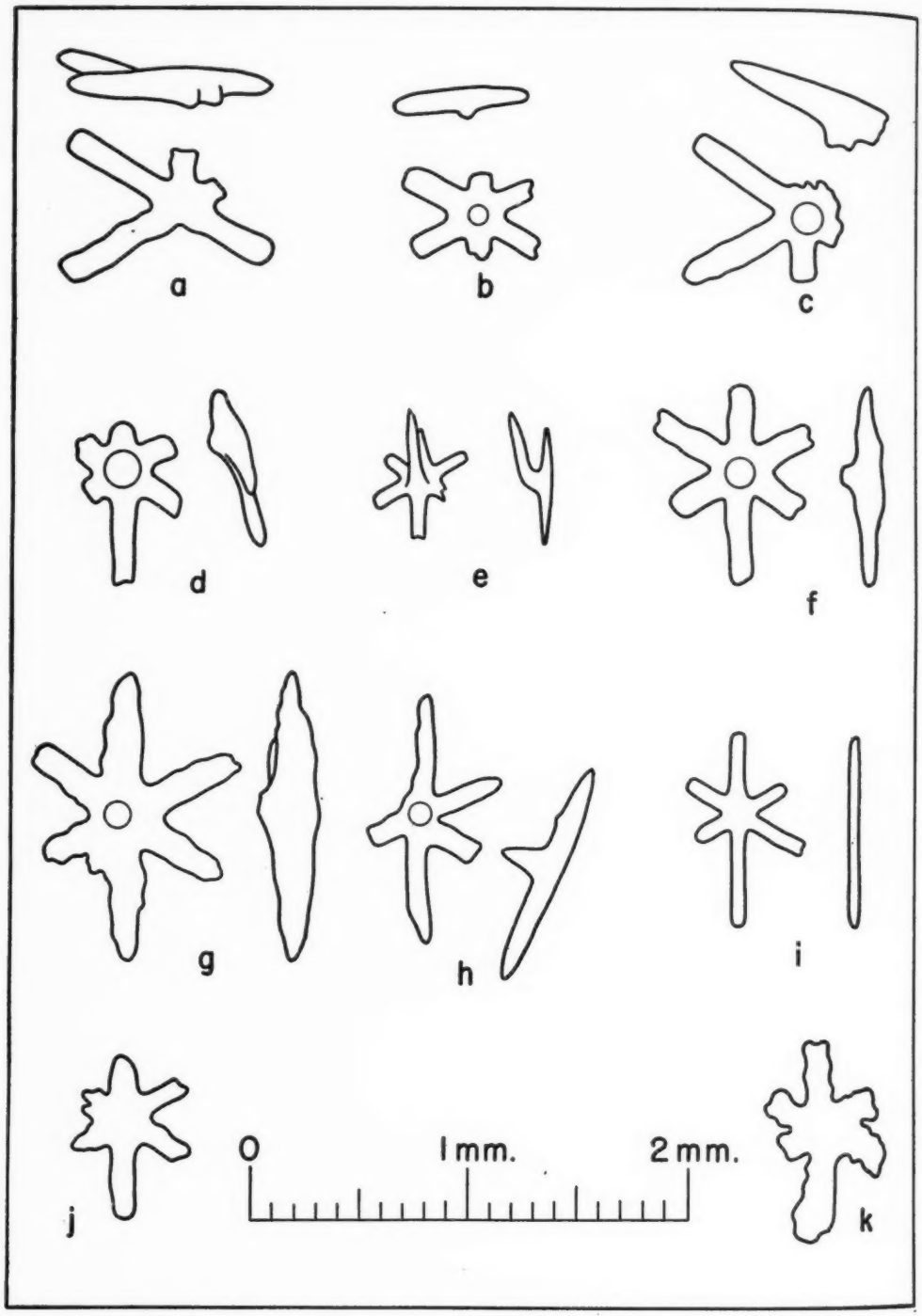

FIG. 2—*Astraeospongia dixonensis* Gutschick, n. sp. *a–k*, drawings made by tracing photographs.

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THE FUSULINID SUBFAMILY BOULTONIINAE

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ABSTRACT—The new subfamily Boultoniinae is proposed to embrace seven Permian fusulinid genera whose geographic and stratigraphic distribution is discussed. One new genus and three species, two of which are new, are described.

INTRODUCTION

IN RECENT years a number of small Permian fusulinid genera have been described from various parts of the world. These have been assigned by various authors to the Schubertellinae, the Fusulininae, or the Schwagerininae. However, they all differ from the Schubertellinae in possessing more or less intensely fluted septa, and from the other two subfamilies in wall structure. At the same time they exhibit a number of characteristics in common which appear to set them aside as a closely related group. We propose the name Boultoniinae for a new subfamily to include the members of this group, with the genus *Boultonia* Lee as the typical genus.

At present we regard *Boultonia* Lee, *Minojapanella* Fujimoto and Kanuma, *Codonofusiella* Dunbar and Skinner, and *Paraboultonia*, n. gen., as definitely belonging to this subfamily. In addition, we are tentatively assigning *Palaeofusulina* Deprat, *Dunbarula* Ciry, and *Gallowaiinella* Chen to this group.

The writers are indebted to the Humble Oil and Refining Company for permission to publish this paper. Special thanks are due Mr. W. A. Rankin, of the Humble Geologic Research Section, who made all of the accompanying photographs.

DISTRIBUTION

Lee (1927) erected the genus *Boultonia*, with *Boultonia willsi* from the Permian of Manchuria as the type species. In the same publication he described *Boultonia rawi* from the Moscovian of the same region. However, *B. rawi* is almost certainly a *Wedekindellina*. The same year Ozawa (1927) described *Schellwienia gracilis*, apparently from the same horizon and locality as that of *Boultonia willsi*. Judging from the descriptions and photographs, the two are conspecific. Since Lee's paper was published three months earlier than that of Ozawa the name *Boultonia willsi* has priority.

Chen (1934) described *Boultonia cylindrica* from the Maping limestone (Lower Permian) of Kwangsi Province, China. However, Chen's description and photographs strongly indicate that his species is a *Schubertella*, rather similar to *S. kingi* Dunbar and Skinner from the Wolfcamp of West Texas. The septa are nearly plane, while those of *Boultonia willsi* are strongly and regularly folded. At the time Chen described his species the common concept of *Schubertella* was based upon the Moscovian forms now known as *Eoschubertella*. Consequently, Chen would not have considered this species to be a *Schubertella* at that time.

Thompson, Wheeler, and Danner (1950) described *Boultonia cascadensis* from the Permian limestone of northwestern Washington where it is associated with *Neoschwagerina*, *Verbeekina*, and *Pseudodoliolina*. Thus it appears to be Middle Permian in age. It differs from *B. willsi* in its more inflated shape and less strongly fluted septa.

Boultonia guadalupensis, n. sp., occurs in the upper Bone Spring limestone of the Guadalupe Mountains of West Texas. It is associated with *Parafusulina*, and its age is probably not greatly different from that of *B. cascadensis*, although the two species are quite different in appearance. A species similar to *B. quadalupensis* has also been found in the beds which Udden (1904) called "the zone of sponge spicules" in the Cibolo formation of the Chinati Mountains, Presidio County, Texas. It now appears probable that this zone is lower Leonardian in age.

From the Trogkofelkalk of the Carnic Alps in Austria we have a few specimens of a *Boultonia* which is very similar to *B. willsi*. In fact, if the two localities were not so

distant from one another we should feel safe in regarding the two as conspecific. We are figuring one of the Trogkofelkalk specimens as *Boultonia willsi?* for comparison with the Chinese material (pl. 42, figs. 11, 12). Associated with *B. willsi?* in the Trogkofelkalk are *Quasifusulina tenuissima* (Schellwien), *Pseudoschwagerina geyeri* Kahler and Kahler, and several species of *Schwagerina*. The presence of *Pseudoschwagerina* would seem to indicate a Wolfcampian or Sakmarian age for the Trogkofelkalk. However, it is known that in southern Europe and in Asia both *Pseudoschwagerina* and *Paraschwagerina* range upward into younger beds. Other considerations suggest that the Trogkofelkalk may be lower Leonardian in age.

An undescribed species of *Boultonia*, which somewhat resembles *B. cascadensis*, occurs in the Upper Permian at Phnom Sampou, Cambodia. It is associated with *Rauserella* sp., *Verbeekina* sp., and *Lepidolina multiseptata* (Deprat).

The specimens which we are here assigning to *Boultonia willsi* occur in the upper part of the Chuanshan limestone in southern Kiangsu Province, China, where they are associated with *Pseudoschwagerina*. We are indebted to Dr. J. S. Lee for the opportunity of studying this material. Although these specimens are not topotypes, they agree so closely in every respect with Lee's original description and photographs that we are convinced they are conspecific with the Manchurian species.

Codonofusiella, with *C. paradoxica* as the type species, was first described by Dunbar and Skinner (1937) from beds of upper Guadalupian age in West Texas. This genus differs from *Boultonia* principally in the possession of an uncoiled gerontic stage. In addition, its septa are more intensely fluted and cuniculi can sometimes be observed. It occurs associated with *Polydiexodina* and *Leëlla*.

Erk (1941) described two species of *Codonofusiella*, as *C. paradoxica* Dunbar and Skinner and *C. nana* Erk, respectively, from the Upper Permian of Turkey. The form which Erk identified as *C. paradoxica* does not appear to be conspecific with the Texas species. Although the two are essentially identical in size there is a marked discrepancy in the intensity of septal folding. The septa of *C. paradoxica* are strongly fluted from pole to pole, while those of the Turkish species are nearly plane across the middle of the shell. In fact, except for the uncoiled gerontic stage, the Turkish species agrees very closely in size and appearance with *Boultonia cascadensis*. *C. nana* is only about half as large as *C. paradoxica*, although the uncoiled gerontic stage indicates that the specimens are mature. The Turkish species are found associated primarily with *Cancellina*, *Neoschwagerina*, *Misellina*, and *Reichelina*. This would suggest that they are somewhat older than *C. paradoxica*. However, Erk states (p. 247) that they also occur at three different localities in the "facies à *Polydiexodina*," indicating that they range upward into beds of upper Guadalupian age.

Thompson, Wheeler, and Danner (1950) described *Codonofusiella duffelli* from the Cache Creek limestone of British Columbia, where it is associated with *Yabeina*. It is probably Upper Permian in age.

Hanzawa (1944) listed a species of *Codonofusiella* from the *Yabeina* zone of the Maiya group in the Kitakami Mountainland of northeastern Japan. He gave no description or figures, saying merely, "The *Codonofusiella* that is found in the *Yabeina* zone in the Kitakami resembles the genotype of the genus, but is usually somewhat smaller in size than the type."

An undescribed species of *Codonofusiella* is present in the Upper Permian limestone of Si-So-Phon, Cambodia, associated with *Lepidolina multiseptata* (Deprat) and *L. elongata* (Gubler).

Recently Fujimoto and Kanuma (1953) described the genus *Minojapanella*, with *M. elongata* as the type species. It is similar to *Boultonia willsi*, but differs in being nearly twice as large and in having much more intense septal fluting. *M. elongata* was found in the Lower Permian Chichibu series of Gifu Prefecture in central Japan where it is associated with *Triticities*, *Schwagerina*, *Staffella*, and *Schubertella*. It apparently is Wolfcampian in age.

We are describing here the new genus *Paraboultonia*, with *P. splendens*, n. sp., as the type species. Our material was collected from a zone about 40 feet below the top of the Bell Canyon formation at the east end of Seven Heart Gap on the northeast flank

of the Apache Mountains, Culberson County, Texas. At this locality it is very abundant in a six-inch bed of brown limestone, literally filling the rock with its shells. We have not found it above or below this narrow zone at this place. A few specimens have been found at about the same stratigraphic level in the Lamar limestone member of the Bell Canyon formation along the Carlsbad-El Paso highway on the north side of Bell Canyon drainage in northern Culberson County. Thus, so far as is now known, *Paraboultonia* is restricted to beds of uppermost Guadalupian age.

Paraboultonia differs from *Boultonia* in its larger size, more intensely fluted septa, and the presence of cuniculi. It differs from *Minojapanella* in possessing a markedly expanded gerontic stage and a different type of septal fluting. It may be distinguished from *Codonofusiella* by the absence of an uncoiled gerontic stage. In this respect it is intermediate between these last two genera.

In addition to the above four genera, we believe the following probably belong to this group.

Ciry (1948) described the genus *Dunbarula*, with *D. mathieui* as the type species, from the Middle Permian of Djebel-es-Souina, southern Tunisia. This genus has rather strongly and regularly folded septa, and a subcylindrical shape with bluntly rounded ends. According to Ciry it occurs in association with *Parafusulina* and *Yabeina* in beds which he correlates with the lower Guadalupian. Dr. Ciry has been kind enough to send us topotypes of this interesting form. In this material we have found one specimen of a small species of *Neoschwagerina*.

Deprat (1912) described the genus *Palaeofusulina* without designating a type species. The following year he described *Palaeofusulina prisca* and designated it as the type species. Deprat's specimens occurred in a "black limestone at Lang-nac" in northern Indochina. He believed this zone to be Visean in age, but later work by Colani (1924) showed it to be Permian, probably Middle Permian.

Palaeofusulina nana was described by Licharev (1926) from the "anthracolithique" of the northern Caucasus. In a later publication Licharev (1939) stated that this species occurs in the "Upper Permian. Northern Caucasus (Basins of the Bela and Laba regions)." It differs from *P. prisca* is being markedly smaller at maturity.

Colani (1924) described *Palaeofusulina prisca* var. *delicata* from Yunnan. She stated that it occurs in a limestone which she regarded as being Uralian in age. The associated fossils indicate a probable Sakmarian age. Colani figured only one tangential and two parallel sections which indicate a form some 3.0 mm. in length and 0.6 mm. in diameter. These sections strongly resemble *Minojapanella*, which occurs in central Japan in rocks of about the same age, and we believe the Yunnanese form should probably be referred to that genus.

Reichel (1940) described and figured a single tangential section from the Permian of the Karakorum as *Palaeofusulina* cf. *P. delicata*. However, it is much smaller than the species figured by Colani, and it possesses axial filling which is absent in the Yunnanese form. It probably should be assigned to *Gallowaiinella*. According to Reichel, it occurs with *Yangchienia* and *Parafusulina* and is probably Middle Permian in age.

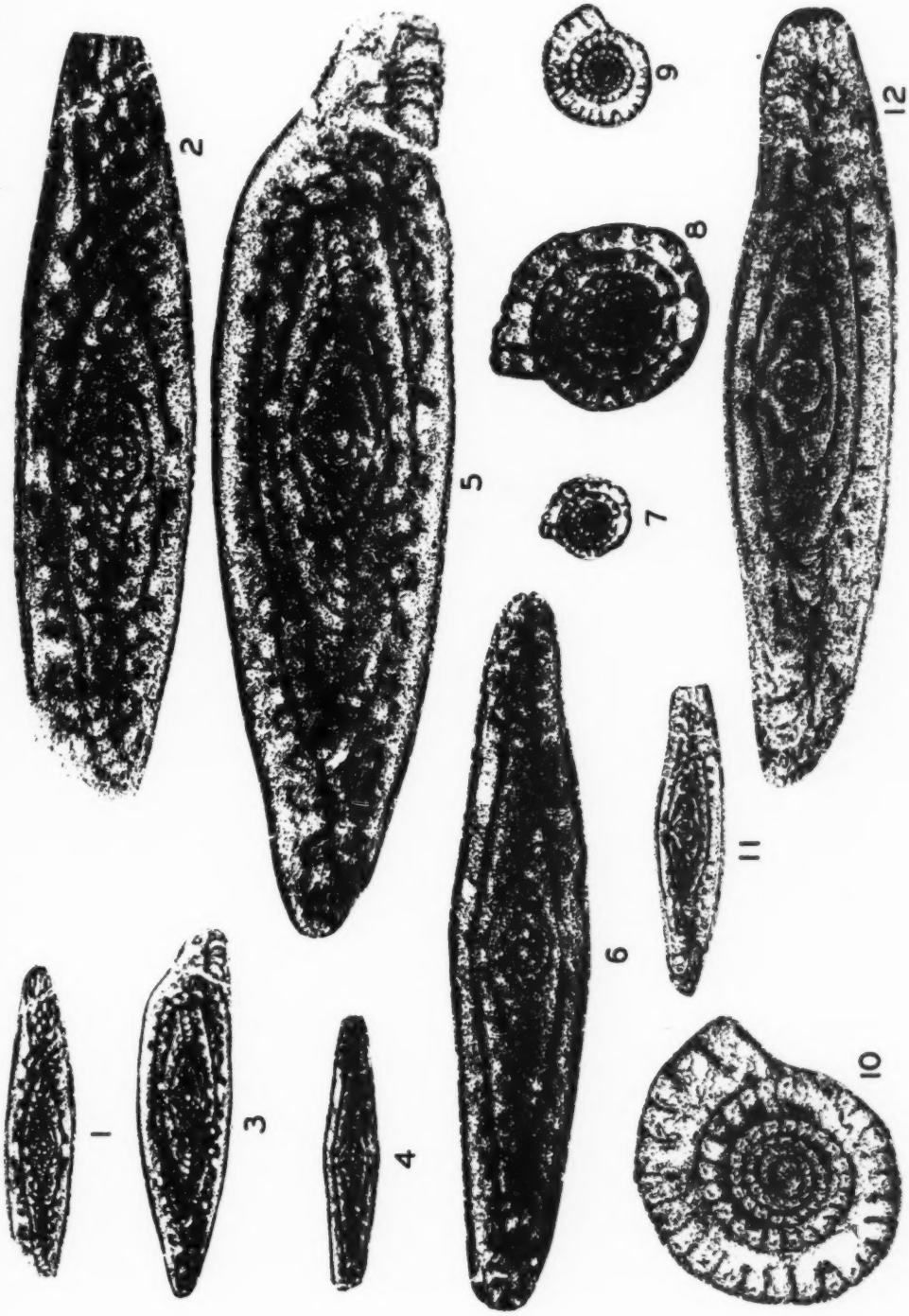
Schubert (1915) described as *Fusulina weberi* a species from the Lower Permian of Timor. Thompson (1949) redescribed this species as *Palaeofusulina weberi* (Schubert). It differs from *P. prisca* and *P. nana*, which are subglobular in shape, in being thickly subcylindrical. Its general shape and size closely approximate those of *Dunbarula mathieui*, from it which differs in having a thinner spirotheca, more intensely folded septa, and a symmetrical juvenarium.

EXPLANATION OF PLATE 42

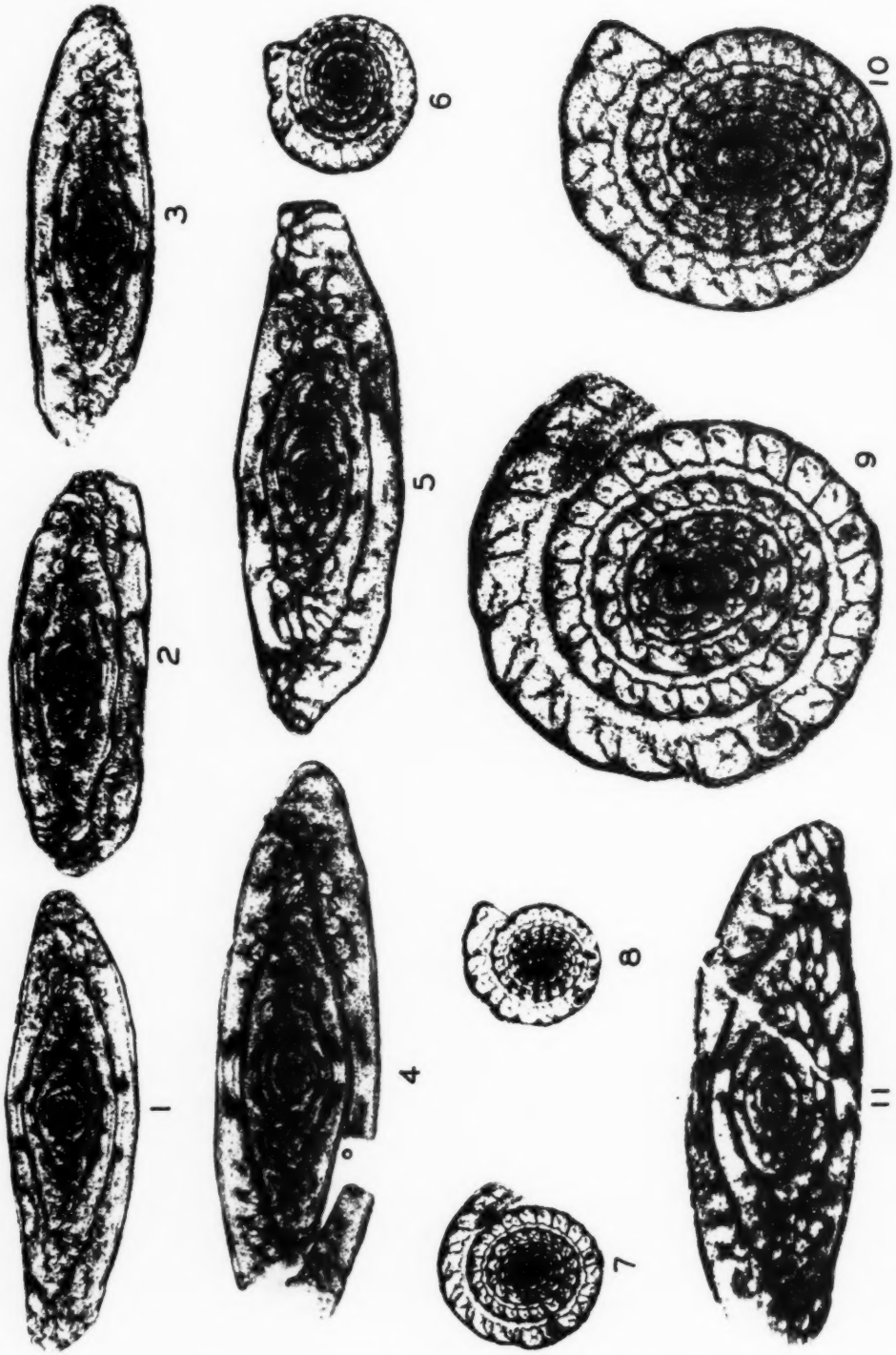
All figures are unretouched photographs.

FIGS. *1–10—Boultonia willsi* Lee, *1*, *3*, *4*, axial sections, ×40; *2*, *5*, *6*, the same specimens, enlarged, ×100; *7*, *9*, sagittal sections, ×40; *8*, *10*, the same specimens, enlarged, ×100. Chuanshan limestone, Chihsiashan, Kiangsu, China. (p. 438)

11, *12—Boultonia willsi* Lee? *11*, axial section, ×40; *12*, the same specimen, enlarged, ×100. Trogkofelkalk, Trogkofel Peak, Carnic Alps, Austria. (p. 435)



Skinner and Wilde, New fusulinid subfamily



Skinner and Wilde, New fusulinid subfamily

Palaeofusulina displays all the common characters of the Boultoniinae, except that it possesses a relatively large proloculus and symmetrical juvenarium rather than a minute proloculus and endothyroid juvenarium. Because of this difference we assign it to this subfamily with reservations.

Chen (1934) described the genus *Gallowaiina*, with *G. meitienensis* as the type species, from a limestone believed to be Middle or Upper Permian in southern Hunan Province, China. Later he learned that this generic name was preoccupied, and in a paper by Dunbar and Skinner (1937) he substituted the name *Gallowaiinella*. This genus, like *Palaeofusulina*, has a rather large proloculus and a symmetrical juvenarium. In addition, it displays rather heavy axial filling. It is the largest of the genera assigned to the Boultoniinae, being over 5 mm. in length. In the same paper Chen described an associated form as *G. meitiensis* var. *evoluta*. If differs from the type species in several important features. It is much smaller, has a minute proloculus, displays no axial filling, and is subglobular in shape as compared to a subcylindrical form in the type species. In addition, it is more loosely coiled than the latter. In all its characters, with the exception of the small proloculus, it closely resembles *Palaeofusulina*, and we are inclined to regard it as belonging to that genus.

SYSTEMATIC DESCRIPTIONS

Subfamily BOULTONIINAE Skinner and Wilde, n. subfam.

The subfamily Boultoniinae includes fusulinids of small size, varying in shape from slender fusiform to subglobular. In all genera except *Palaeofusulina* and *Gallowaiinella* the proloculus is minute and the juvenarium, which is coiled askew to the outer whorls, is lenticular or discoidal in shape. The spirotheca is composed of a tectum and a thin diaphanotheca. In *Dunbarula* the chomata deposits extend across the floor of the tunnel and part way up the septa, giving the appearance, in sagittal sections, of an outer tectorium and a thickening of the distal ends of the septa. However, this material is not a true tectorium, being confined to the equatorial region of the shell. Another peculiarity of *Dunbarula* is the abrupt change in the appearance of the diaphanotheca as it bends inward to extend down the posterior face of the septum. At this point the diaphanotheca, which in the spiral wall is rather dense and semi-opaque, abruptly becomes clear and transparent. Ciry has called this clear element of the septa the *feuillet septal*. The relationship between the spirothecal and septal portions of the diaphanotheca is probably analogous to that between the keriotheca and the pyknotheca of the schwagerinids. In the outer whorls, what appears to be a very fine-textured keriothecal structure can sometimes be seen.

Abundant septal pores are common to all members of this group, with the possible exception of *Boultonia willsi*. We believe them to be present in this species, as well, but the preservation of our material does not permit us to be certain.

Finally, all members of the Boultoniinae display one character which is rather difficult to put into words. In thin sections the spirotheca of even the best preserved specimens has a translucent to transparent quality which produces a glassy or resinous appearance. This feature is, perhaps, most marked in *Boultonia willsi* and *Minojapanella elongata*. In these two species, one can actually see through the spirotheca of an unsectioned specimen and distinguish some of the internal structures. This translucency often makes it difficult to observe minute structures because of the lack of contrast

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EXPLANATION OF PLATE 43

All figures are unretouched photographs.

FIGS. *1–10*—*Boultonia guadalupensis* Skinner and Wilde, n. sp. *1–4*, axial sections of paratypes, ×40; *5*, axial section of the holotype, ×40; *6–8*, sagittal sections of paratypes, ×40; *9*, *10*, specimens shown in *7* and *8*, enlarged, ×100. Upper Bone Spring formation, Bone Canyon, Guadalupe Mountains, Culberson County, Texas. (p. 439)

11—*Boultonia* sp. Axial section, ×40. "Zone of sponge spicules," Cibolo formation, Chinati Mountains, Presidio County, Texas. (p. 441)

between the shell material and the clear calcite which fills the chambers.

One should not confuse this character with the poor preservation invariably displayed by such genera as *Ozawainella* and *Staffella*. The latter probably possessed a shell of different chemical composition, and recrystallization or replacement often obscures even the major features. The members of the Boultoniinae, on the other hand, are usually well preserved, and it is only the minute details that are difficult to distinguish clearly.

Genus BOULTONIA Lee, 1927
BOULTONIA WILLSI Lee
Plate 42, figures 1–10

Boultonia willsi LEE, 1927, Palaeontologia Sinica, ser. B. vol. 4, fasc. 1, pp. 10, 11, pl. 2, figs. 1–4.

Fusulina (*Schellwienia*) *gracilis* OZAWA, 1927, Japanese Jour. Geology and Geography, vol. 5, pp. 83, 84, pl. 7, figs. 5, 6.

Shell minute, slender fusiform, with sharply pointed poles. Mature specimens consist of 5 to 6 volutions, the first 1½ to 2 being discoidal and coiled askew to the outer ones. Length varies from 1.27 to 1.54 mm. and width from 0.26 to 0.31 mm. in the fifth volution. From ratio averages 4.6 in mature individuals.

The spirotheca is very thin and is composed of a tectum and a thicker, light colored inner layer, presumably the diaphanotheca, in which no structure can be seen. The septa are thin and rather strongly and regularly fluted from pole to pole. They are composed of the same elements which make up the spirotheca. Because of the minute size it is usually impossible to count the septa in the juvenarium; however, the number seems to vary between 10 and 15.

The proloculus is minute and essentially spherical, varying from 30 to 37 microns in outside diameter. The tunnel is low and narrow, following a somewhat erratic course. It is bordered by high, narrow chomata which persist into the outermost whorl.

Because a sagittal section of an adult specimen will invariably present an axial section of the juvenarium, it is possible to count the septa of such sections only in the whorls outside the juvenarium. The above table assumes that the juvenarium in each case consists of two complete volutions.

TABLE OF MEASUREMENTS (IN MILLIMETERS)

Specimen	Half Length					
	0	1	2	3	4	5
A	.015	—	—	.285	.608	—
B	.018	—	—	.310	.539	.777
C	.015	—	—	.338	.503	—
D	.015	—	—	.279	.515	—

Specimen	Half Diameter					
	0	1	2	3	4	5
A	.015	.048	.063	.099	.151	—
B	.018	.052	.069	.101	.132	.182
C	.015	.039	.055	.077	.104	—
D	.015	.034	.055	.082	.121	.168

Specimen	Ratio of HL/HD					
	0	1	2	3	4	5
A	1.0	—	—	2.9	4.0	—
B	1.0	—	—	3.1	4.1	4.3
C	1.0	—	—	4.4	4.8	—
D	1.0	—	—	3.4	4.3	—

Specimen	Thickness of Spirotheca					
	0	1	2	3	4	5
A	.004	.007	.008	.010	.010	—
B	.004	.006	.007	.008	.010	.011
C	.006	.006	.008	.008	.010	—
D	.006	.006	.008	.008	.010	—

Specimen	Tunnel Angle				
	1	2	3	4	5
A	—	—	32	37	—
B	—	—	15	26	26
C	—	—	19	23	—
D	—	—	—	22	36

Specimen	Septal Count					
	1	2	3	4	5	6
E	—	—	13	17	22	—
F	—	—	13	17	20	26

Discussion.—The above description is based on Lee's original description, supplemented by observations on the material now before us. Although our specimens did not come from the type locality, they agree so closely with Lee's description and figures that we feel no hesitancy about assigning them to *Boultonia willsi*. Because Lee's description gave few statistical measurements

we consider it useful to redescribe the species in greater detail.

Occurrence.—This species was first described by Lee from the third limestone from the bottom of the section in the Wuhutsui coal field, Manchuria. Three months later Ozawa described a species, from the same zone and locality as *Fusulina (Schellwienia) gracilis*. A comparison of the descriptions and photographs of the two forms leaves little doubt that they are conspecific. The name *Boultonia willsi*, of course, has priority. In any event, the name *Fusulina gracilis* is preoccupied by *Fusulina gracilis* Meek, which has a priority of many years.

Our specimens came from a piece of Chuanshan limestone from Chihsiashan, southern Kiangsu Province, China. In the same piece of rock are several specimens of *Pseudoschwagerina orientale* Huzimoto. This material was made available to us through the kindness of Dr. J. S. Lee.

BOULTONIA GUADALUPENSIS Skinner and Wilde, n. sp.
Plate 43, figures 1–10

Schubertella sp. NEWELL, et al., 1953, W. H. Freeman & Co., pl. 17, fig. 4.

Shell minute, slender subcylindrical, with bluntly pointed to rounded poles. Mature individuals possess 5 to 6 volutions, the first 1½ to 2 of which are discoidal and coiled askew to the later whorls. Length varies from 1.73 to 2.08 mm. and diameter from 0.52 to 0.62 mm. in the sixth volution. Form ratio of mature shells averages 3.5.

The spirotheca is very thin and consists of a tectum and a thin diaphanotheca. The septa are thin and composed of the same elements as the spirotheca. They are moderately fluted toward the ends of the shell, but are only slightly wavy across the central portion. They are pierced by abundant septal pores which usually appear to be more numerous in the upper half of each septum. In addition, a very regularly spaced row of pores is often observed along the basal margins of the septa. These pores seem to have been partially or completely plugged with epithecal deposits, and, consequently, they appear as darker spots on the translucent septa, rather than as holes in the latter. It seems probable that, as the tunnel was excavated through a septum, the pores in that septum were no longer physiologically necessary and were then filled with the same sort of deposit as that making up the chomata. Usually it is difficult to count the septa in the juvenarium; however, in three specimens this number varies from 18 to 23.

The proloculus is minute and spherical, ranging from 35 to 50 microns in outside diameter. The tunnel is low and relatively wide, and it is bordered by rather strong chomata for a shell with such thin walls.

Discussion.—*Boultonia guadalupensis*, n. sp., is readily distinguished from *Boultonia willsi* Lee by its larger size, lower form ratio, and less strongly fluted septa. From *Boultonia cascadensis* Thompson, Wheeler, and Danner it differs in its larger size, higher form ratio, and somewhat weaker septal folding.

Occurrence.—*Boultonia guadalupensis* is fairly abundant in the top of a small bioherm in the upper part of the Bone Spring limestone in the south wall of Bone Canyon,

TABLE OF MEASUREMENTS (IN MILLIMETERS)

Specimen	Half Length						
	0	1	2	3	4	5	6
A	.023	—	—	.199	.299	.589	.873
B	.024	—	—	.218	.479	.746	—
C	.020	—	—	.270	.454	.803	—
D	.024	—	—	.279	.534	.693	—
E	.021	—	—	.208	.459	.824	—
F	.017	—	—	.192	.389	.728	1.115
G	.023	—	—	.231	.415	.715	—
H	.024	—	—	.180	.369	.796	1.238

(*continued on next page*)

Specimen	Half Diameter						
	0	1	2	3	4	5	6
A	.023	.044	.073	.110	.152	.234	.338
B	.024	.062	.089	.120	.179	.283	—
C	.020	.041	.063	.106	.162	.254	—
D	.024	.044	.072	.108	.177	.283	—
E	.021	.055	.083	.113	.169	.254	—
F	.017	.037	.065	.096	.141	.210	.314
G	.023	.066	.094	.125	.170	.235	—
H	.024	.054	.092	.134	.189	.283	.396

Specimen	Ratio of HL/HD						
	0	1	2	3	4	5	6
A	1.0	—	—	1.8	2.0	2.5	2.6
B	1.0	—	—	1.8	2.7	2.6	—
C	1.0	—	—	2.5	2.8	3.2	—
D	1.0	—	—	2.6	3.0	2.4	—
E	1.0	—	—	1.8	2.7	3.2	—
F	1.0	—	—	2.0	2.8	3.5	3.6
G	1.0	—	—	1.8	2.4	3.0	—
H	1.0	—	—	1.3	2.0	2.8	3.1

Specimen	Thickness of Spirotheca						
	0	1	2	3	4	5	6
A	.008	.010	.010	.020	.020	.028	.024
B	.008	.008	.010	.015	.023	.031	—
C	.007	.007	.008	.018	.021	.025	—
D	.006	.007	.011	.014	.020	.020	—
E	.007	.007	.011	.015	.017	.023	—
F	.007	.007	.008	.008	.015	.023	.025
G	.008	.008	.013	.017	.020	.024	—
H	.008	.007	.010	.015	.014	.023	.018

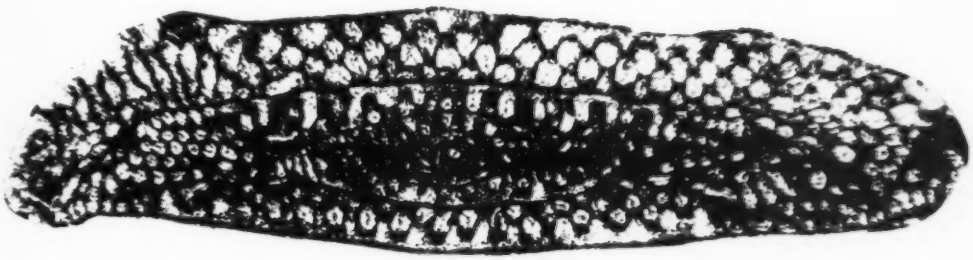
Specimen	Tunnel Angle					
	1	2	3	4	5	6
A	—	—	21	26	44	50
B	—	—	19	26	41	—
C	—	—	18	28	64	—
D	—	—	—	23	46	—
E	—	—	14	29	51	—
F	—	—	—	20	33	67
G	—	—	15	19	41	—
H	—	—	11	21	37	58

Specimen	Septal Count					
	1	2	3	4	5	6
I	—	—	12	14	19	21
J	—	—	16	21	24	26
K	—	—	15	17	20	—
L	—	—	16	22	26	—
M	—	—	13	15	21	24

EXPLANATION OF PLATE 44

All figures are unretouched photographs.

FIGS. *1–7*—*Paraboultonia splendens* Skinner and Wilde, n. gen., n. sp. *1*, axial section of the holotype, ×40; *2–4*, axial sections of paratypes, ×40; *5–7*, sagittal sections of paratypes, ×40. Upper Bell Canyon formation, Apache Mountains, Culberson County, Texas. (p. 441)



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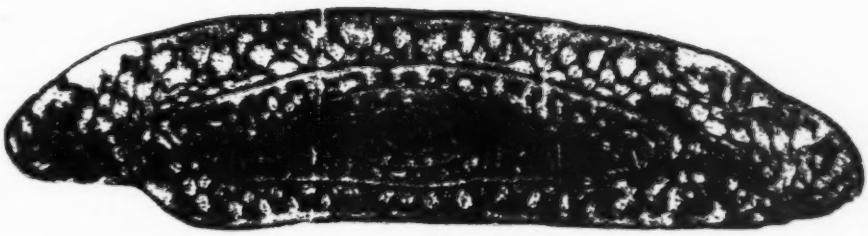

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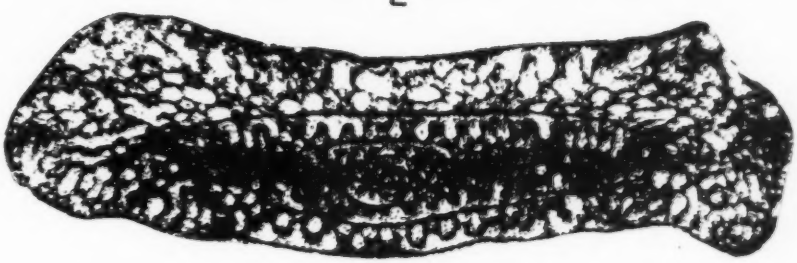

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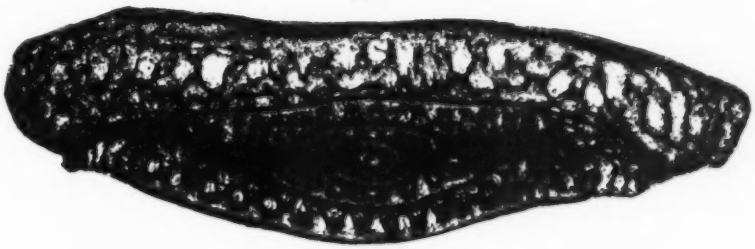

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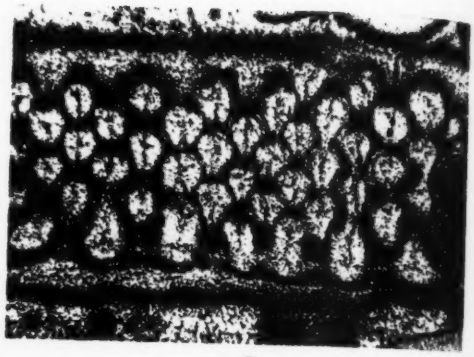
7

Skinner and Wilde, New fusulinid subfamily

1



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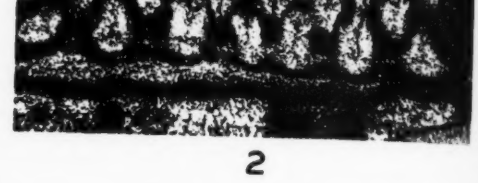
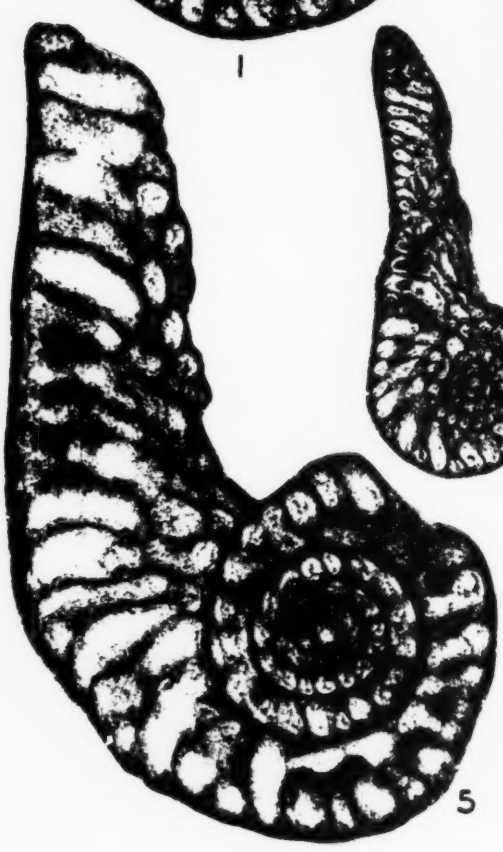


3

4



5

6

7

Skinner and Wilde, New fusulinid subfamily

near the mouth of the canyon, on the west side of the Guadalupe Mountains, Culberson County, Texas. It is less abundant in the top of a similar bioherm at about the same horizon and a short distance south of the mouth of Bone Canyon. These bioherms are about 80 feet below the base of the Brushy Canyon formation at that place.

In addition, we have found a very similar form in the cherty limestones which Udden (1904) called "the zone of sponge spicules" in the Cibolo formation of the Chinati Mountains, Presidio County, Texas. Specimens which appear to be conspecific have been observed in limestones of Leonard age in cuttings from several wells in both the Midland and Delaware basins.

Genus PARABOULTONIA Skinner and Wilde, n. gen.

Genotype: *Paraboultonia splendens* Skinner and Wilde, n. sp.

Diagnosis.—Shell minute, slender cylindrical, with bluntly rounded poles. Mature specimens consist of 4½ to 5½ volutions and attain a length of 3.5 mm. The maximum equatorial diameter observed is 0.85 mm. The proloculus is minute and is followed by a discoidal juvenarium which usually consists of a single volution, but may occasionally include 1½ volutions. The juvenarium is coiled about an axis that is oriented in a direction about 90 degrees from that of the later whorls. The spirotheca and septa are very thin and are composed of a tectum and a diaphanotheca. The septa are intensely fluted from pole to pole, and cuniculi are developed in the outer whorls. Septal pores are abundant. In mature specimens the final quarter volution expands markedly. The tunnel is singular, very narrow, and erratic in its course. It has not been observed beyond the end of the fourth volution. Very weak chomata are present in the first two whorls but are absent in the later stages of growth.

Discussion.—Only the type species is known at present. It more closely resembles *Minojapanella elongata* Fujimoto and Kanuma than any other described species. It differs from the latter in several respects, the most important being the great expansion in the final whorl and the possession of cuniculi. In addition, both the tunnel and the chomata are present in the outer whorls in *Minojapanella*, while in *Paraboultonia* chomata have not been observed beyond the second whorl nor a tunnel beyond the fourth. Through the kindness of Professor H. Fujimoto we have been able to study topotype specimens of *Minojapanella*.

Paraboultonia somewhat resembles *Codonofusiella* Dunbar and Skinner; however, the shell of the latter completely uncoils in the final whorl to produce a flaring flange which is larger than the coiled portion of the shell. In the uncoiled part of *Codonofusiella* the lower margin of each septum is folded back against the face of the preceding septum (pl. 45, figs. 5, 6) and does not reach the outer surface of the preceding volution. On the other hand, in *Paraboultonia*, the septa of the expanded portion of the final whorl, including the antetheca, all extend down to the outer surface of the penultimate volution (pl. 44, figs. 5–7; pl. 45, fig. 1).

Age.—At present, *Paraboultonia* is known only from beds of uppermost Guadalupian age.

PARABOULTONIA SPLENDENS Skinner and Wilde, n. sp.

Plate 44, figures 1–7; plate 45, figures 1–4

Shell minute, slender cylindrical, with bluntly rounded poles. Mature specimens possess 4½ to 5½ volutions, the first of which

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EXPLANATION OF PLATE 45

All figures are unretouched photographs.

FIGS. *1–4*—*Paraboultonia splendens* Skinner and Wilde, n. gen., n. sp. *1*, sagittal section of a paratype, ×100; *2*, *3*, parts of two tangential sections, ×100, showing the septal fluting in plan. A cuniculus appears to the right of center in each figure. *4*, sagittal section of an immature paratype, ×40. Upper Bell Canyon formation, Apache Mountains, Culberson County, Texas. (p. 441)

5–7—*Codonofusiella paradoxica* Dunbar and Skinner. *5*, sagittal section, ×100; *6*, sagittal section, ×40; *7*, axial section, ×40. In this last specimen the lateral ends of the uncoiled flange were broken off prior to fossilization. These figures are included for comparison with *Paraboultonia splendens*. Lower Altuda formation, Glass Mountains, Brewster County, Texas. (p. 435)

is discoidal in shape and coiled askew to the outer ones. Length varies from 2.5 to 3.5 mm. and diameter from 0.62 to 0.85 mm. Form ratio of mature individuals varies from 3.3 to 5.5, averaging 4.0. In the final whorl the last quarter of a volution is rather abruptly expanded. This expansion may take place at any point after the beginning of the fifth volution, but appears to occur most commonly at about the end of $4\frac{1}{2}$ whorls.

The spirotheca and septa are very thin, consisting of a tectum and a diaphanotheca. The septa are intensely fluted from pole to pole, the fluting being very regular except in the expanded portion of the final whorl. Cuniculi have been observed in the outer whorls. Septal pores are abundant and are similar in appearance to those described above in *Boultonia guadalupensis*, n. sp. The number of septa in the juvenaria of two specimens is 16 and 17, respectively. In both specimens the juvenaria include approximately $1\frac{1}{4}$ whorls.

The proloculus is minute and usually spherical, although in occasional specimens it may be slightly ellipsoidal in shape. Its outside diameter ranges from 49 to 73 microns, averaging about 60 microns. The tunnel is low, very narrow, and erratic in its

TABLE OF MEASUREMENTS (IN MILLIMETERS)

Specimen	Half Length						
	0	1	2	3	4	5	6
A	.036	—	.175	.479	1.109	1.967	
B	.036	—	.159	.414	1.030	—	
C	.022	—	.115	.403	.778	1.353	
D	.033	—	.175	.438	.888	—	
E	.030	—	.115	.364	.679	1.271	—
F	.025	—	.181	.625	1.142	—	

Specimen	Half Diameter						
	0	1	2	3	4	5	6
A	.036	.070	.094	.131	.193	.358	
B	.031	.054	.100	.169	.273	—	
C	.024	.046	.087	.141	.235	.417	
D	.033	.059	.101	.170	.287	—	
E	.030	.051	.085	.131	.199	.308	—
F	.025	.080	.118	.190	.341	—	

Specimen	Ratio HL/HD						
	0	1	2	3	4	5	6
A	1.0	—	1.9	3.7	5.7	5.5	
B	1.2	—	1.6	2.4	3.8	—	
C	0.9	—	1.3	2.9	3.3	3.2	
D	1.0	—	1.7	2.6	3.1	—	
E	1.0	—	1.4	2.8	3.4	4.1	—
F	1.0	—	1.5	3.3	3.3	—	

Specimen	Thickness of Spirotheca						
	0	1	2	3	4	5	6
A	.010	.008	.008	.011	.015	.025	
B	.008	.007	.010	.013	.015	—	
C	.007	.007	.008	.011	.015	.021	
D	.007	.007	.008	.011	.020	—	
E	.008	.008	.011	.014	.015	.021	—
F	.007	.008	.008	.014	.021	—	

Specimen	Tunnel Angle				
	1	2	3	4	5
A	—	—	16	17	—
B	—	15	24	22	—
C	—	—	20	23	—
D	—	—	22	20	—
E	—	—	24	22	—
F	—	—	24	—	—

Specimen	Septal Count					
	1	2	3	4	5	6
G	—	17	25	33	—	
H	—	—	14	22	31	—
I	—	15	18	24	30	—
J	—	12	17	25	—	
K	—	—	15	25	34	—

course. We have never observed it beyond the fourth whorl, and in one specimen it cannot be seen beyond the third. Very weak chomata are present in the first two volutions, but are absent thereafter.

Discussion.—*Paraboultonia splendens*, n. sp., is the only representative of this genus known at present. The only other described form with which it might be confused is *Minojapanella elongata* Fujimoto and Kanuma. However, as pointed out above, it is readily distinguished from the latter by the abrupt expansion which takes place near the end of the ultimate volution, and by the absence of chomata and tunnel in the outer whorls. The tunnel disappears at about the growth stage in which the cuniculi appear, and it is possible that the latter took over the function of the tunnel in the outer volutions.

Occurrence.—This species occurs in great profusion in a six-inch limestone bed about 40 feet below the top of the Bell Canyon formation near the east end of Seven Heart Gap, on the northeast side of the Apache Mountains, southern Culberson County, Texas. We have also found occasional specimens in the upper part of the Lamar limestone member of the Bell Canyon formation in cuts along the Carlsbad-El Paso highway near the crest of the escarpment on the north side of Bell Canyon, northern Culberson County, Texas. Thus, so far as is known at present, it appears to be confined to a thin zone of uppermost Guadalupian age.

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FUSULINID WALL STRUCTURE

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ABSTRACT—Recent work has suggested a new interpretation of the nature of the profusulinellid wall, and this concept is here presented for the first time; remarkably preserved material gives a more precise picture of the minute structure of the fusulinellid spirotheca; photographic evidence is presented for the first time, demonstrating the presence of a keriothecal structure in the wall of *Sumatrina* and *Lepidolina*.

INTRODUCTION

For more than twenty years primitive fusulinids, possessing a three-layered spirotheca, have been known to occur in beds of early Pennsylvanian age. It has always been assumed that these components of the spiral wall consisted of a single primary layer, the tectum, and two secondary layers, the inner and outer tectoria. Recent work with excellently preserved material has enabled the writers to obtain photographic evidence that this concept is in error, and this evidence is presented here.

We wish to acknowledge our indebtedness to the Humble Oil and Refining Company for permission to publish this paper, and to Mr. W. A. Rankin, of the Humble Geologic Research Section, for the preparation of the photographs which accompany it

THE PROFUSULINELLID WALL

The most primitive type of fusulinid spirothecal structure known, the profusulinellid wall, was first pointed out by Lee and Chen (1930) in describing the Moscovian genus *Fusiella*. The spirotheca of *Fusiella*, according to Lee and Chen, was made up of three layers consisting of an outer tectorium, a tectum, and an inner tectorium. Later, Skinner (1931) described under the name *Fusiella primaeva* a species with a similar wall structure from the Brook member of the Big Saline formation in Kimble County, Texas. In the same paper Skinner also described *Schubertella gallowayi* from the Cherokee formation of Mayes County, Oklahoma. This species, which also exhibits a profusulinellid spirotheca, was later transferred to the genus *Eoschubertella*.

The genus *Profusulinella* was erected by Rauser-Chernoussova and Beljaev (1936) for a species from the Moscovian of Russia. It differs from *Fusiella* in its larger size and ovate or thickly fusiform shape, but displays a three-layered wall which is apparently identical with that of *Fusiella*. Until recently the present authors were inclined to regard *Profusulinella* as a synonym of *Fusiella;* now, however, we have had an opportunity to study topotypes of the type species of the latter genus, and we are convinced that the two genera are distinct. Perhaps the most outstanding difference is the discrepancy in size. We have shown specimens of the two genera at the same magnification (pl. 46, figs. 1, 2) for direct comparison. Accordingly, we are transferring *Fusiella primaeva* Skinner to the genus *Profusulinella*.

Thompson (1948) described a number of species of *Profusulinella* from the pre-Des Moines Pennsylvanian beds of West Texas and New Mexico. At the same time he assigned *Profusulinella primaeva*, with question, to the genus *Fusulinella*. This was done because this species sometimes displays, in a sporadic and discontinuous manner, what appears to be a four-layered wall such as that which is characteristic of *Fusulinella*. However, this feature is not consistent. Some specimens show only a three-layered wall, while others display four layers only here and there within the test. In no case have the authors seen a specimen which exhibits four layers throughout the entire shell, or even throughout one complete whorl.

It has long been known that the tectoria, where present, were secondary in origin and were deposited as a lining of the chambers. Thus, the deposit which, on the floor of a

chamber, became the outer tectorium of one whorl was, on the ceiling of that chamber, the inner tectorium of the next whorl. The secondary nature of this material is demonstrated by the fact that its deposition lags several chambers behind the forward growth of the shell. As a consequence, the last few chambers at any stage of growth have a spirotheca composed only of the primary elements. Furthermore, since the tectorium is deposited as a lining of the chambers, it is obvious that there will be no outer tectorium in the spirotheca of the outer whorl at any stage of growth.

In such genera as *Fusulinella* and *Fusulina* the penultimate whorl commonly possesses a spirotheca composed of four layers, the outer tectorium, the tectum, the diaphanotheca, and the inner tectorium. The outermost whorl has a three-layered wall consisting of tectum, diaphanotheca, and inner tectorium, except for the last few chambers which have a wall composed of only the tectum and diaphanotheca. These last two layers may be considered as the primary elements of the wall and apparently were deposited nearly simultaneously. In well preserved specimens the diaphanotheca can be seen to extend down both the posterior and anterior faces of the septa.

The profusulinellid wall, in the penultimate whorl, displays three layers. These are a thin, dark tectum covered inside and out by thicker, lighter colored layers. The latter have heretofore been considered as the inner and outer tectoria, respectively, and this type of wall was supposed to have no diaphanotheca. Thus, *Fusulinella* was believed to have developed from *Profusulinella* by the addition of another primary layer, the diaphanotheca, between the tectum and the inner tectorium. The occasional appearance of a four-layered wall in *Profusulinella primaeva* would be considered, according to this interpretation, as evidence that this is an advanced species, transitional to *Fusulinella*, in which an incipient diaphanotheca was in the process of developing. However, we find it difficult to visualize the development of a second primary layer, *in patches*, between two previously existing elements of the wall.

Recently we have obtained sagittal sections of well preserved profusulinellids in which the outer whorl and the antetheca are intact. According to the current interpretation the spirotheca and septa of the last few chambers should be composed only of the tectum, supposedly the only primary element of the profusulinellid wall. However, our specimens show that the spirotheca and septa of these final chambers do not differ in any way from those of the remainder of the ultimate whorl. The walls and the septa of these chambers, including the antetheca, are composed of the tectum and an inner, thicker, lighter-colored layer. The latter, traced back into the interior of the shell, is identical with the layer which has been considered to be the inner tectorium. But since it is present in the antetheca, and therefore essentially contemporaneous with the tectum, it must be regarded as primary in origin and cannot be considered as a secondary element such as the tectorium. Furthermore, the outer tectorium of the penultimate whorl, which is a part of the floor of the final volution, can often be seen to end rather abruptly before these final chambers are reached. These relationships are clearly shown in the accompanying photographs (pl. 46, figs. 6–9; pl. 47, figs. 3, 4, 7, 8).

A consideration of this evidence leads to the following conclusions:

1. The inner layer of the profusulinellid wall is a diaphanotheca rather than an

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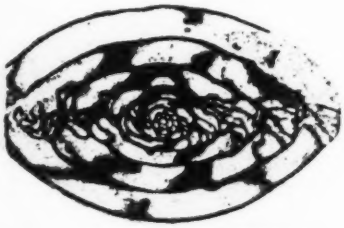
EXPLANATION OF PLATE 46

All figures are unretouched photographs.

FIG. *1*—*Fusiella typica* Lee and Chen. Axial section, ×20, for comparison with fig. *2* to show difference in size between *Fusiella* and *Profusulinella*. Huanglung limestone, Kwanshan, Lungtan, China.

2–9—*Profusulinella decora* Thompson. *2*, axial section, ×20; *3–5*, sagittal sections, ×20; *6*, part of the specimen shown in *3*, enlarged, ×100; *7*, part of the specimen shown in *4*, enlarged, ×100; *8*, *9*, part of the specimen shown in *5*, enlarged, ×100 and ×200. These enlargements show the two-layered character of the antetheca and of the spirotheca of the final chambers. Apodaca formation, Powwow Canyon, Hueco Mountains, El Paso County, Texas.



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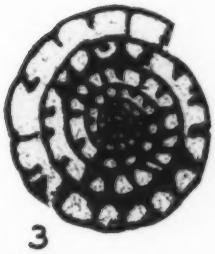

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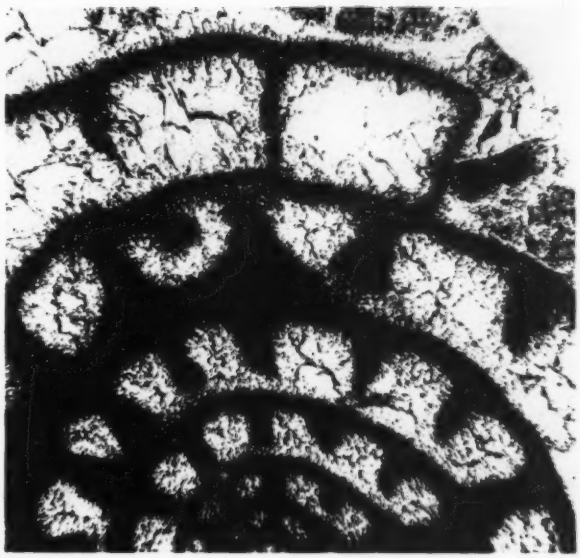

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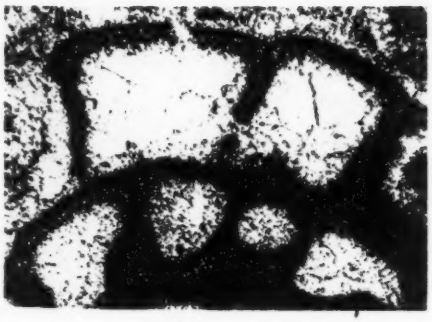

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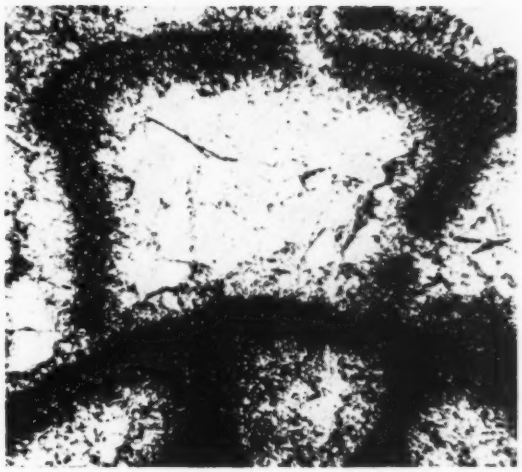

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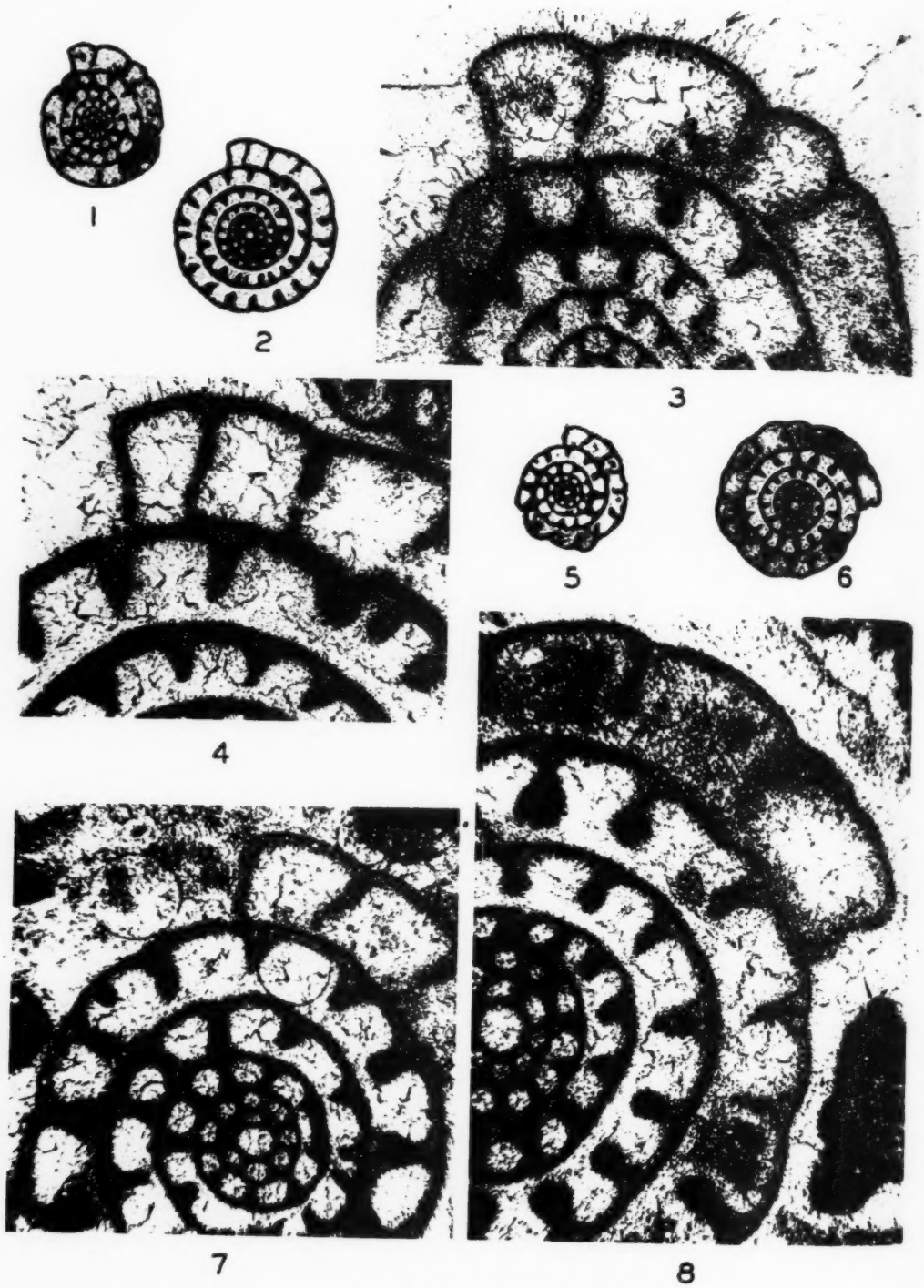
Skinner and Wilde, Fusulinid wall structure



Skinner and Wilde, Fusulinid wall structure

inner tectorium, and the three layers of the wall are the outer tectorium, the tectum, and the diaphanotheca, respectively.

2. In forms having a profusulinellid wall the tectorium is deposited only on the floor of the chambers, and, perhaps, a short distance up the septal partitions.
3. In highly advanced profusulinellids, such as *Profusulinella primaeva*, the tectorium may occasionally be deposited thinly on the ceiling of a few chambers, producing a four-layered wall at those places.
4. In such genera as *Fusulinella*, *Fusulina*, and *Wedekindellina* the tectorium completely lines the chambers, producing the typical four-layered fusulinellid wall.

It may be objected that the diaphanotheca in the fusulinellids is commonly lighter in color than the tectoria, while the inner and outer layers of the profusulinellid wall appear equally dense. However, we have seen numerous examples of typical *Fusulinella* and even *Fusulina* in which the diaphanotheca and outer tectorium are of equal density, although, at a glance, the diaphanotheca appears the lighter of the two. The latter effect, in these examples, is at least partly an illusion created by the fact that the diaphanotheca is sandwiched between the darker tectum and inner tectorium and appears lighter by contrast. In such specimens the inner tectorium is definitely darker than the outer tectorium (pl. 48, figs. 1, 2).

Since the inner tectorium of one whorl is continuous with the outer tectorium of the preceding whorl, it is difficult to understand why the same deposit should be darker on the ceiling of a given chamber than on the floor. Gubler (1934, 1935) postulated that the varying density of the several layers of the spirotheca is due to variations in the percentage of organic matter. He stated that the shell was composed of minute globulites of calcite cemented together by a dark brown organic substance called "tectine." In those layers which appear very dark, such as the tectum, the globulites were very small and the interstitial tectine cement was relatively thick. In lighter colored layers the globulites were somewhat larger and were cemented together with a thinner film of tectine. Gubler dissolved the calcite from thin sections in very weak acid solutions and was able to confirm that the residue was a fine meshwork of dark organic matter.

If we accept Gubler's explanation we can only conclude that the tectorium on the ceiling of a chamber has a higher tectine content than that on the floor, although at present we can postulate no reasons for such a differentiation. However, our observations indicate a progressive change in the density of the outer tectorium. In the profusulinellids and the primitive fusulinellids the apparent density of the outer tectorium is essentially the same as that of the diaphanotheca, while in the more advanced fusulinellids it often becomes as dark as the inner tectorium.

THE FUSULINELLID WALL

As indicated above, the fusulinellid wall commonly exhibits a four-layered appearance. These elements are the tectum, diaphanotheca, and the inner and outer tectoria. The septa, in all except the last few chambers of the outer whorl, are similarly composed except that the diaphanotheca extends down both the anterior and posterior faces of the septa (pl. 49, fig. 1).

EXPLANATION OF PLATE 47

All figures are unretouched photographs.

FIGS. *1, 3—Profusulinella decora* Thompson. *1*, sagittal section, ×20; *3*, part of same specimen, enlarged, ×100, showing the two-layered antetheca.

2, 4–8—Profusulinella munda Thompson. *2*, *5*, *6*, sagittal sections, ×20; *4*, part of specimen shown in *2*, enlarged, ×100; *7*, part of specimen shown in *5*, enlarged, ×100; *8*, part of specimen shown in *6*, enlarged, ×100. Enlargements show the two-layered character of the antetheca and of the spirotheca of the final chambers. All specimens on this plate are from the Apodaca formation, Powwow Canyon, Hueco Mountains, El Paso County, Texas.

For many years the fusulinellid wall was thought to be imperforate. However, White (1932), Dunbar and Skinner (1937), Henbest (1937), and Dunbar and Henbest (1942) have been able to demonstrate the presence of minute tubules, or "mural pores," penetrating all four layers of the spirotheca.

We are fortunate in having at our disposal a collection of several species of *Fusulina* in which the mural pores, which are normally invisible, have been filled with an iron mineral and stand out in sharp contrast. Although such pores have been figured before, the present material shows them with a greater clarity than any photographs previously published. Our material was collected from a very locally developed lens of conglomeratic limestone about 30 feet below the top of the Mingus shale in western Parker County, Texas. This locality, which was discovered by Wilde in 1951, is 5.9 miles southeast of the Baker Hotel in Mineral Wells on the old Mineral Wells-Millsap road.

It has been supposed in the past that the dark- and light-colored layers of the wall might, in part, be due to the constriction and expansion, respectively, of the tubules. Our material shows that the diameter of the tubules is essentially the same in all layers (pl. 48, fig. 4; pl. 49, figs. 2, 4; pl. 50, figs. 1, 3).

In addition to the Mingus material, we have several specimens of *Fusulinella prolifica* Thompson from the Atoka formation of Oklahoma which are similarly preserved (pl. 50, figs. 2, 4, 6). These were collected by Mr. Robert Roth at a locality 0.25 miles north of the southwest corner of Section 2, T. 1 S., R. 8 E., Coal County, Oklahoma. In this same material we have found a specimen of *Millerella marblensis* Thompson which exhibits the same natural staining (pl. 49, fig. 3). Although the presence of mural pores in *Millerella* has been generally assumed, we believe that this is the first time that they have been clearly demonstrated.

THE *SUMATRINA* WALL

Nearly all fusuline students have characterized the spirotheca of the genus *Sumatrina* as being composed of a single thin, compact layer, the tectum. So far as the writers know, only Colani (1924) and Gubler (1935) noted the presence of a thin keriotheca in this genus. Colani cited, with reservations, the appearance of such an element in her material from Indochina. She believed the keriotheca to be present but stated that she could not be certain of it. Gubler stated flatly that a keriotheca is present in *Sumatrina annae* Volz and in *Sumatrina longissima* Deprat. However, neither Gubler nor Colani presented any photographic evidence of the existence of such a structure in these species. In addition, Gubler stated that the tectum invariably participates in the formation of the septula in *S. longissima* and occasionally in *S. annae*, just as it does in the septa.

We have been able to study exceptionally well preserved specimens of *Sumatrina annae* from the Upper Permian limestone of Japan. This material was collected by Yabe

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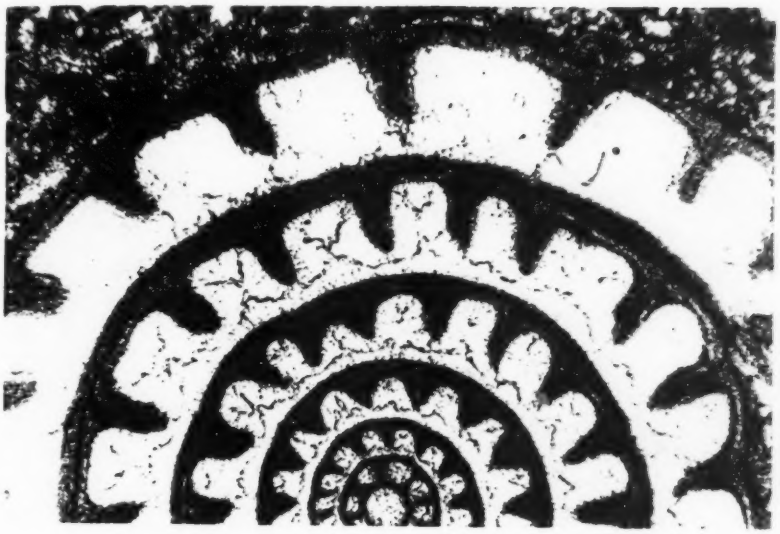
EXPLANATION OF PLATE 48

All figures are unretouched photographs.

FIG. *1*—*Fusulinella llanoensis* (Thomas). Part of a sagittal section of a topotype, ×100. To the left of the figure, where little or no inner tectorium is present, the diaphanotheca and outer tectorium appear equal in density and the spirotheca resembles that of a profusulinellid; to the right a thin, very dark inner tectorium is present and the spirotheca has a typically fusulinellid appearance. Soldiers Hole member of Big Saline formation, Pfluger Bluff, Kimble County, Texas.

2—*Fusulina rockymontana* Roth and Skinner. Part of a sagittal section of a topotype, ×100. At the top of the figure the diaphanotheca and the outer tectorium are of equal density, although the former appears lighter because of its proximity to the much darker inner tectorium. McCoy formation, McCoy, Eagle County, Colorado.

3, 4—*Fusulina* sp. *3*, part of a parallel section, ×100, showing the mural pores extending through all layers of the spirotheca; *4*, part of the same specimen, enlarged, ×200. The tubules of the mural pores have been filled with an iron mineral, causing them to appear as black lines in the photographs. Upper part of Mingus shale, Parker County, Texas.



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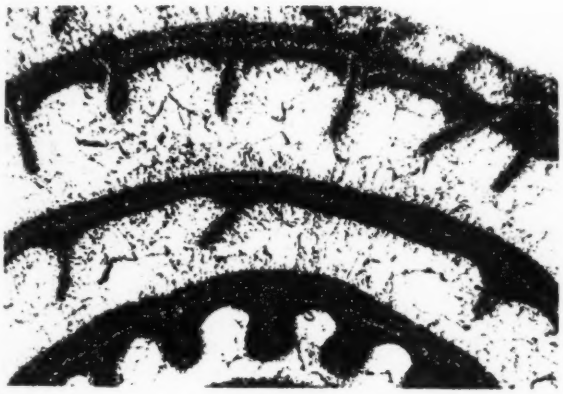

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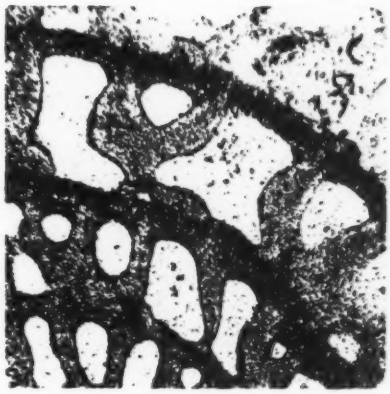

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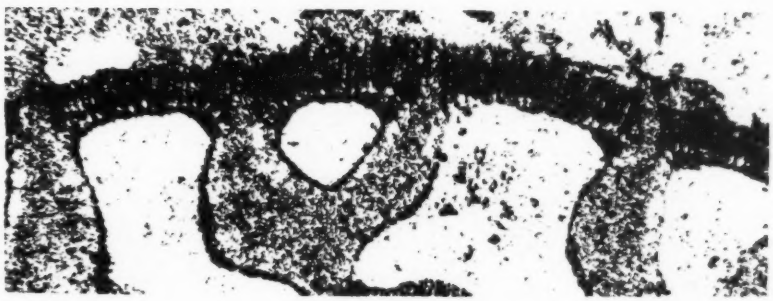

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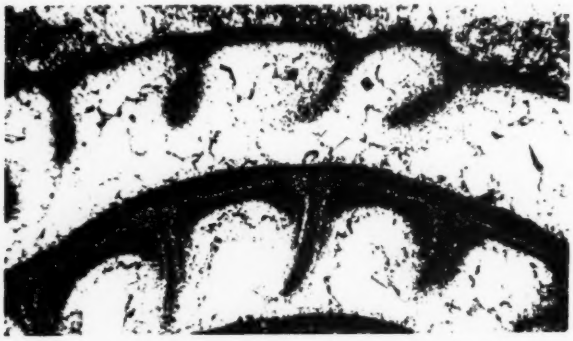
Skinner and Wilde, Fusulinid wall structure



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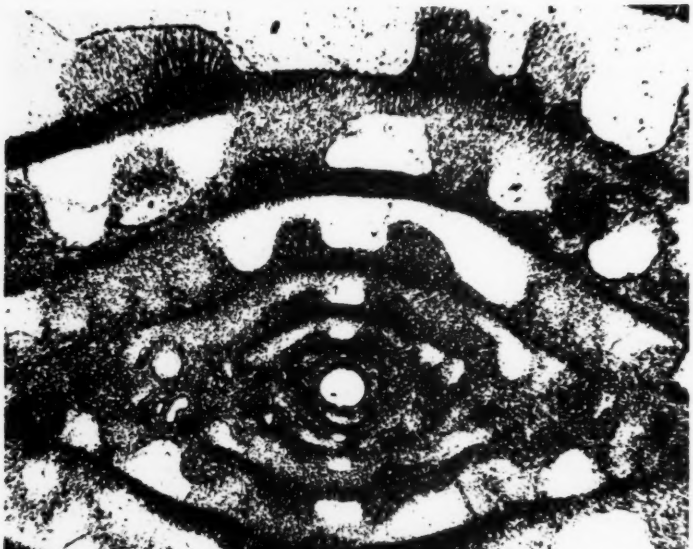

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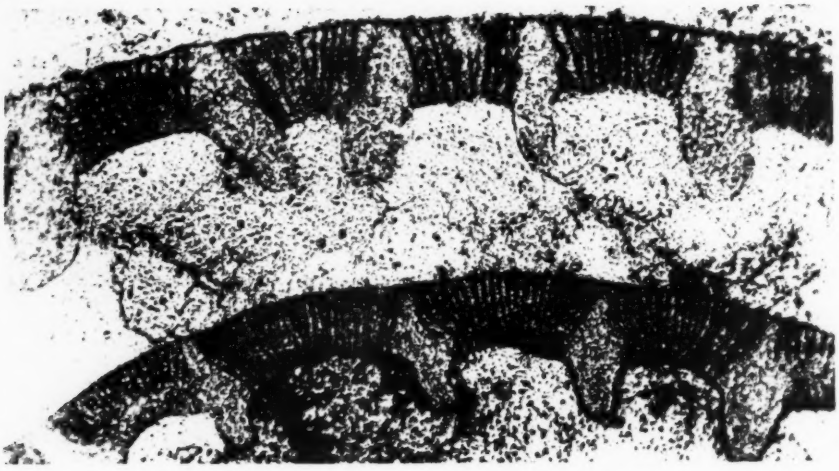

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Skinner and Wilde, Fusulinid wall structure

and Ozawa from Iwakurayama, Hinaga, Ominé-mura, Miné-gun, Nagato Province, Yamaguchi Prefecture. We are indebted to Dr. Yabe for making this material available.

Our specimens amply confirm Gubler's contention that a thin, very fine-textured keriotheca is present in *Sumatrina*. However, they do not bear out his conclusions that the tectum is involved in the formation of the septula. The accompanying photographs (pl. 51, figs. 2–4) show that while the tectum is sharply indented immediately above each septulum it does not extend down into the latter. The septula of *Sumatrina annae* are formed, as in other members of the Neoschwagerininae, by elongated elements of the keriotheca. These are thickened and consolidated at their tips by a deposit of secondary material. We believe that this is the first time that photographic evidence of a keriotheca in *Sumatrina* has been published.

Recently Dr. E. Saurin, Director of the Service Géologique of Indochina, sent us topotypes of *Sumatrina longissima* Deprat from Phnom Miai (Don Mear), Cambodia. The material is very well preserved, but the wall is so thin that when sufficient magnification is used to resolve the layers of the spirotheca the tiny calcite granules of which the shell is constructed obscure the minute structure. Thus, it is virtually impossible to obtain photographs which show the actual spirothecal structure. When thin sections are examined at high magnification with a binocular microscope, the spirotheca commonly appears to be composed of a single compact layer, much thinner than the spirotheca of *Sumatrina annae*. However, one can see here and there, that the wall actually consists of two layers. These are a very thin, dark outer layer, presumably the tectum, and a less dark, slightly thicker inner layer in which a very fine-textured keriothecal structure can be distinguished. Although the wall is sharply indented above each septulum, we have been unable to see any evidence that the tectum participates in the formation of the septula, and we are inclined to disagree with Gubler's conclusions in this respect. We believe that suitably preserved specimens would show that the septula of *Sumatrina longissima*, like those of other members of the Neoschwagerininae, are simply stalactitic elongations of elements of a very thin and very fine-textured keriotheca.

THE *LEPIDOLINA* WALL

Deprat (1912) described a large neoschwagerinid as *Neoschwagerina* (*Sumatrina*) *multiseptata*. Although he stated that he had found the species both at Fong-Wou-Chann in Yunnan province, China, and at Si-So-Phon in Cambodia, all of his figured specimens came from the latter place, and it seems rather obvious that his description was based on specimens from this locality. Hence, Si-So-Phon may be regarded as the type locality of the species.

Deprat regarded this species as a connecting link between *Neoschwagerina* s. s. and *Sumatrina*. At first he considered the latter to be a subgenus of *Neoschwagerina*, but in a later paper (1914) he dropped the subgeneric classification and regarded *Sumatrina* as a distinct genus. Although he still considered the Cambodian species to be transitional between the two genera, he believed it to be more closely related to *Sumatrina* than to *Neoschwagerina* and accordingly classified it as *Sumatrina*.

Deprat's reasons for such a conclusion were the thinness and marked consolidation

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EXPLANATION OF PLATE 49

All figures are unretouched photographs.

FIG. *1*—*Fusulinella* sp. Part of a sagittal section, ×100, showing the diaphanotheca extending down both sides of the septa. Upper part of Soldiers Hole member of Big Saline formation, Soldiers Hole, McCulloch County, Texas.

2, 4—*Fusulina* sp. *2*, part of an axial section, ×100; *4*, part of a sagittal section, ×200. Mural pores appear as dark lines because they are filled with an iron mineral. Upper part of Mingus shale, Parker County, Texas.

3—*Millerella marblensis* Thompson. Tangential section, ×300. Mural pores have been filled with an iron mineral and appear as dark lines crossing the spirotheca. Atoka formation, Coal County, Oklahoma.

of the septula and his belief that the spirotheca between the septula was devoid of keriotheca and was composed of the tectum alone. According to his interpretation, the septula were composed of very fine elongated alveoli, but no keriotheca was present between adjacent septula. Since he believed the spirotheca of *Sumatrina* to be composed solely of the tectum, it appeared to him that only a slight further consolidation of the septula was needed to convert this species into a true *Sumatrina*.

Later, Colani (1924) and Gubler (1935) stated that *Sumatrina multiseptata* has a thin, but distinct, keriotheca and assigned the species to *Neoschwagerina*.

Lee (1933) proposed the new genus *Lepidolina*, with *Lepidolina multiseptata* (Deprat) as the type species. It is not clear from Lee's discussion whether or not he possessed specimens of *L. multiseptata*. However, he figured two specimens from Kweichow which he considered to be congeneric. According to Lee, "the wall is almost entirely devoid of keriotheca." He considered it to be distinct from *Sumatrina*, however, because it possesses both primary and secondary axial septula, while *Sumatrina* has only short, presumably secondary, axial septula. He states, "As far as the minute structure of the wall, septa, and septula is concerned *Lepidolina* differs little from *Sumatrina*."

More recently, various authors have accepted Lee's diagnosis and have considered the wall of *Lepidolina* as being composed solely of the tectum.

Unfortunately, none of the photographs published by any of these authors is of sufficient magnification or clarity to demonstrate the nature of the *Lepidolina* spirotheca in an unmistakable manner. Recently, through the courtesy of Dr. E. Saurin, we have obtained topotypes of *Lepidolina multiseptata* from Si-So-Phon (pl. 52, figs. 1–5). This material clearly shows that *Lepidolina* does possess a thin, but quite distinct, keriotheca. In thickness and fineness of texture it is comparable to that of *Afghanella* Thompson. Furthermore, at high magnifications it can be seen that the septula, while thin, are not so completely consolidated as Lee's description would lead one to believe. They can be seen to be composed of elongated elements of the keriotheca, as stated by Deprat, Colani, and Gubler, becoming completely consolidated only near their distal margins. Thus, *Lepidolina* differs from *Yabeina* only in the extreme thinness of the keriotheca and of the septula, and in the slightly greater consolidation of the latter, the differences being in degree and not in kind.

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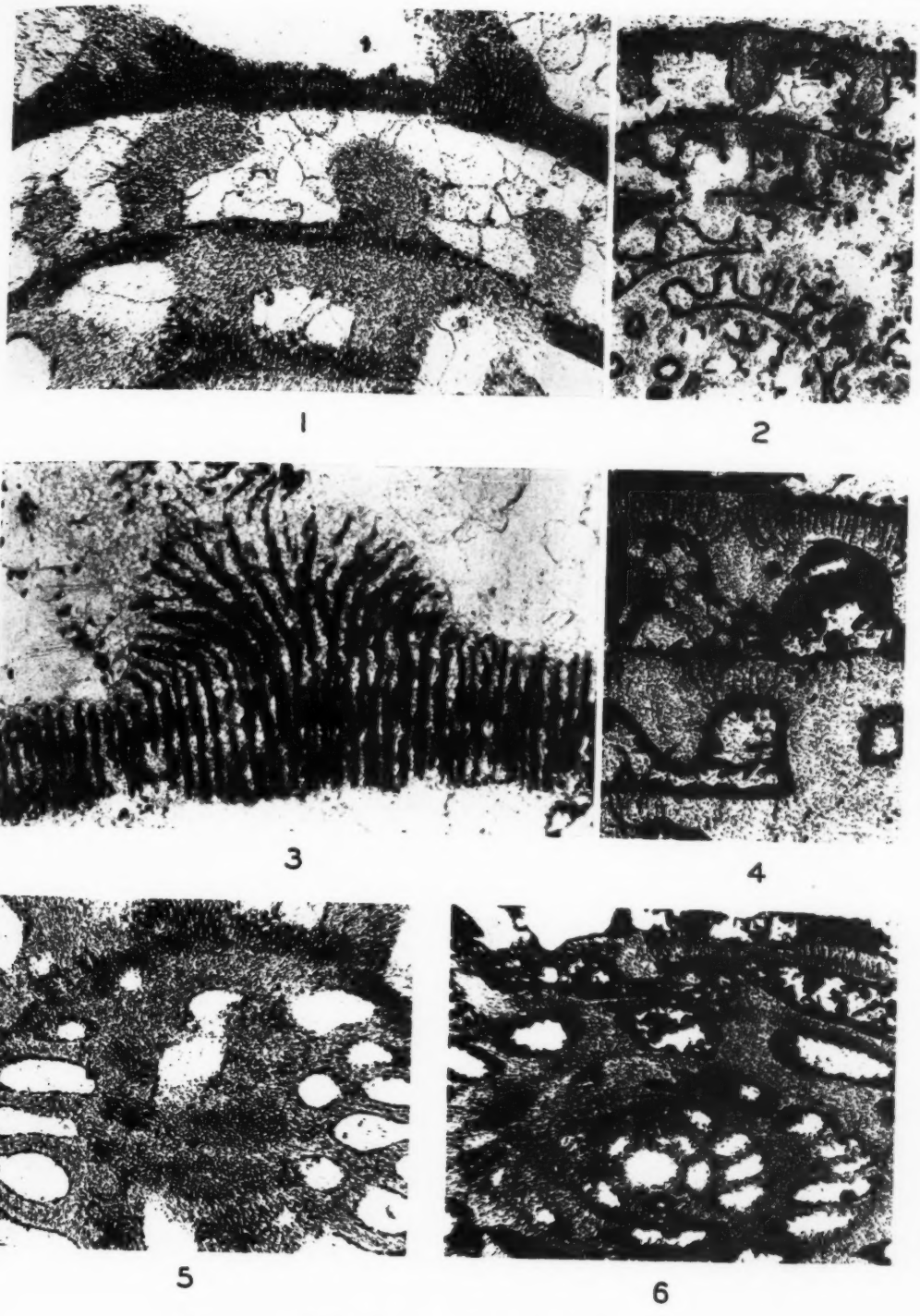
EXPLANATION OF PLATE 50

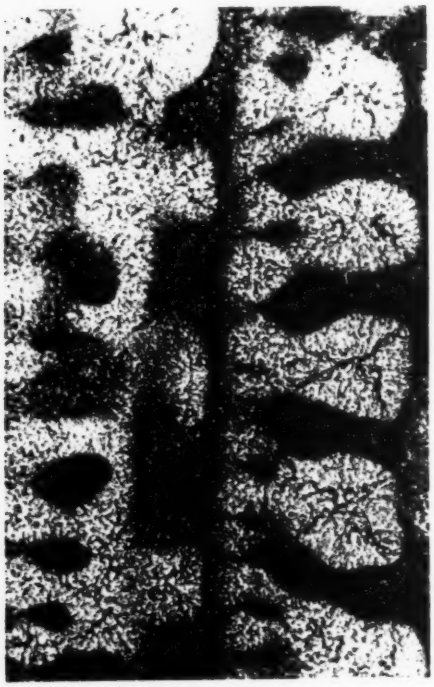
All figures are unretouched photographs.

FIGS. *1*, *3*, *5*—*Fusulina* sp. *1*, part of a tangential section, ×100; *3*, part of the same specimen, enlarged, ×325; *5*, another part of the same specimen, ×100, showing an end on view of the mural pores. Mingus shale, Parker County, Texas.

2, *4*, *6*—*Fusulinella prolifica* Thompson. *2*, *4*, parts of a sagittal section, ×100 and ×200, respectively; *6*, part of an oblique section, ×100. Atoka formation, Coal County, Oklahoma.



Skinner and Wilde, Fusulinid wall structure



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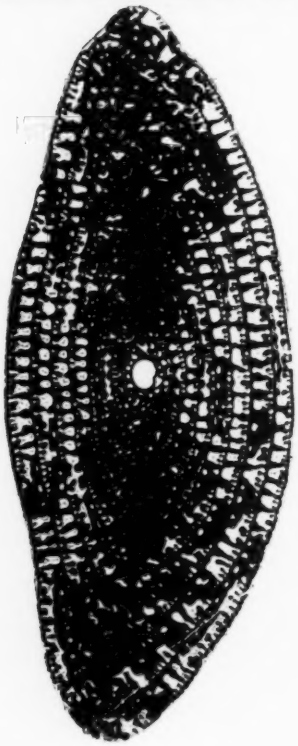

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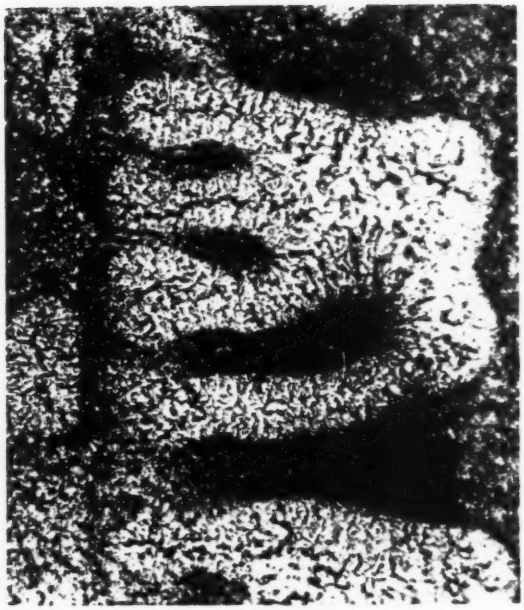

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Skinner and Wilde, Fusulinid wall structure

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EXPLANATION OF PLATE 51

All figures are unretouched photographs.

FIGS. *1–4*—*Sumatrina annae* Volz. *1*, axial section ×20; *2*, *3*, parts of the same specimen, enlarged, ×200 and ×300, respectively, showing the presence of a thin keriotheca; *4*, part of a sagittal section, ×100, showing the sharp indentation of the spirotheca above the septula. Upper Permian, Iwakurayama, Hinaga, Ominé-mura, Miné-gun, Nagato Province, Japan.

(*Please turn the page for Plate 52*)

EXPLANATION OF PLATE 52

All figures are unretouched photographs.

FIGS. *1–5*—*Lepidolina multiseptata* (Deprat). *1*, axial section of a topotype, ×10; *2*, sagittal section of a topotype, ×10; *3*, *4*, parts of two sagittal sections of topotypes, ×100, showing the presence of a thin keriotheca; *5*, part of an axial section of a topotype, ×100, Upper Permian, Si-So-Phon, Cambodia.

JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 4, PP. 452–464, PL. 53, 2 TEXT FIGS., JULY 1954

STRATIGRAPHIC DISTRIBUTION AND CORRELATION OF SOME MIDDLE DEVONIAN OSTRACODA

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Carter Oil Company, Jackson, Mississippi

ABSTRACT—Detailed stratigraphic collections from Middle Devonian strata of northwestern Ohio, west-central New York, and southwestern Ontario, Canada, have yielded 53 species of ostracodes, of which six are new. Correlation of these strata by means of ostracode distribution data suggests a higher stratigraphic position for the Silica shale than previous work indicated.

INTRODUCTION

THIS paper is a regional study of some Middle Devonian ostracodes in portions of northwest Ohio, west-central New York and southwestern Ontario, Canada. In order to obtain as accurate a regional picture as possible, complete stratigraphic samples were collected and their ostracode faunas carefully studied.

Numerous efforts have been made to afford a more comprehensive correlation for the Devonian than now exists. The greatest difficulty encountered seems to be the lack of paleontologic rather than lithologic evidence. Existing correlations, when based on paleontology, have been made principally with the aid or use of megafossils, with little or no reference to microfossils, particularly ostracodes.

The value and necessity of descriptive work in micropaleontology are fully appreciated, but the writer believes that too little emphasis has been placed on the stratigraphic distribution of fossils. Stratigraphic studies of ostracodes may aid materially in making accurate subsurface correlations from well samples and in detailed correlation of strata exposed at the surface. Studies of this type should be made from many fossil assemblages, collected at carefully determined horizons, from as many localities as possible.

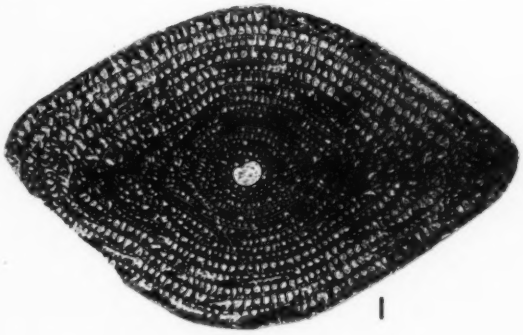
The wide geographic and stratigraphic distribution of Devonian ostracodes is indicated by the numerous contributions in the literature. An examination of relatively recent papers shows little utilization of ostracodes for stratigraphic correlation. Many of the descriptions have been based on assemblages taken from a very few restricted localities. It seems probable that in some cases the collections have been made indiscriminately with too little regard to the accurate position in the stratigraphic column. This practice has resulted in the erection of a maximum number of species having a minimum value for purposes of correlation. Lack of stratigraphic data is frequently demonstrated by the meagre knowledge of the intraspecific and interspecific relationships found in many species.

Another problem with which stratigraphers are faced is the validity of species. A new genus or species has no practical value until the geologic range has been carefully worked out. Insofar as there are no definite criteria for the delineation of species, it is left to the discretion of the author as to how species should be classified. The resulting overlapping and erroneous classification of species create a disheartening barrier to any who should attempt a detailed stratigraphic or paleontologic problem.

Acknowledgements.—The writer is deeply indebted to Dr. John T. Sanford, who suggested the problem and supervised the work. Thanks are due to Messrs. M. E. Simons and George Stolt for their assistance in measuring sections and collecting samples, and to Mr. Hebert L. Tischler for his aid in preparing plates.

The author especially wishes to thank

[1] Submitted to the Graduate Council of Wayne University, Detroit, Michigan, in partial fulfillment of the Master of Science degree, 1950.



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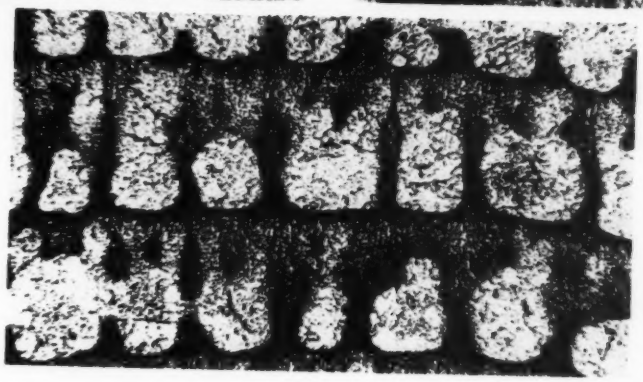

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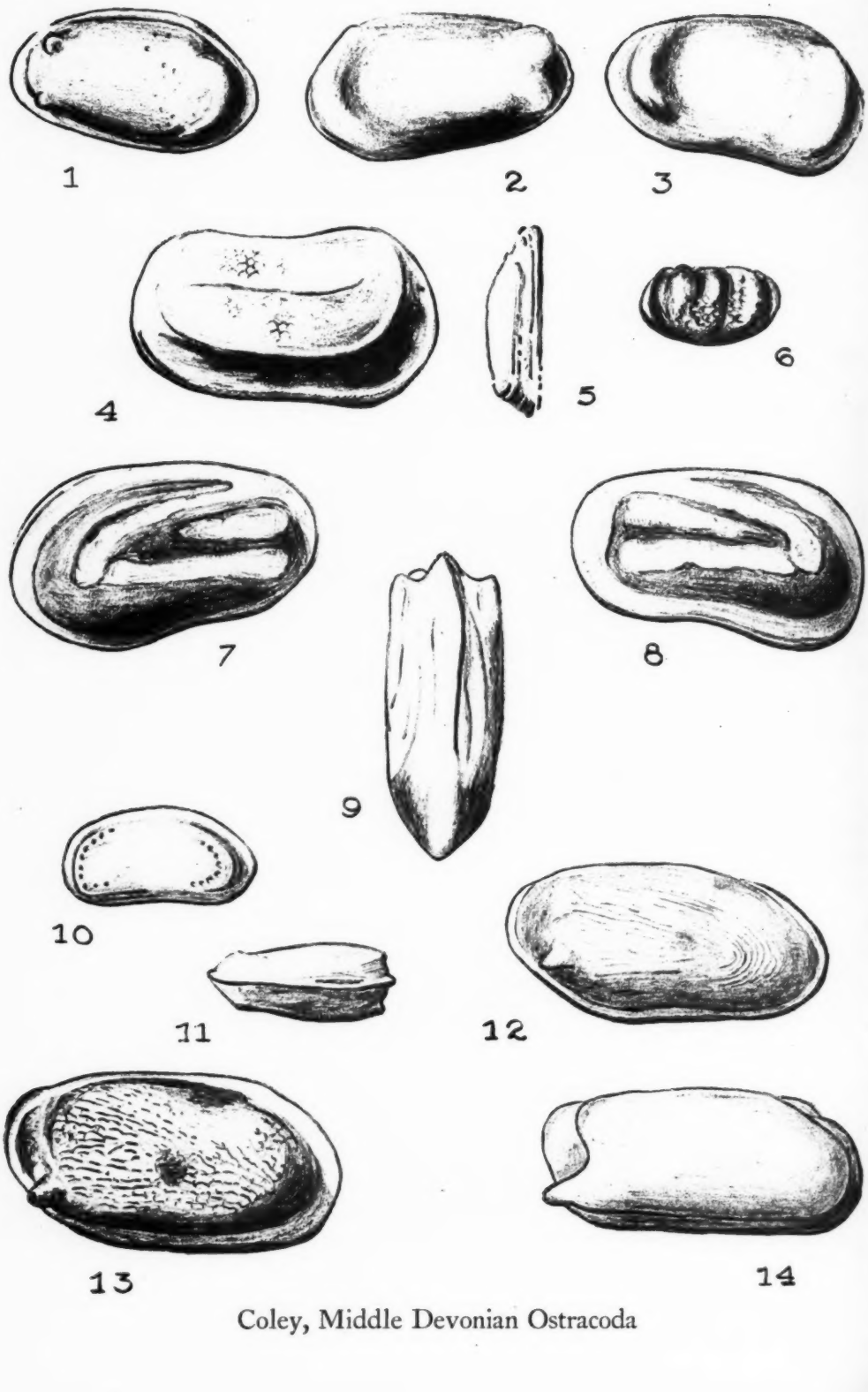
Skinner and Wilde, Fusulinid wall structure



Coley, Middle Devonian Ostracoda

Mrs. Jean Davies Wright for her kindness in preparing the drawings.

The author also wishes to thank the Society of Sigma Xi for their research award which enabled him to carry out a more extensive field collection than would otherwise have been possible.

Field data.—Field work was done in the summers of 1948 and 1949. Samples were collected from exposures near Canandaigua and Geneseo, New York; Sylvania, Ohio; and Arkona, Ontario, Canada. The sections collected are given below.

New York: Centerfield formation: (Canandaigua Quadrangle, 5th/9th). Exposure at type locality on Schaffer Creek, 9/10 mile north of the village of Centerfield on Highway 20. Total thickness, 8 ft. 7 in.

Ledyard, Wanakah, Tichenor, Deep Run and Menteth formations: (Caledonia Quadrangle 6th/9th). Exposures at Jacox Run, approximately 2½ miles north of the town of Geneseo. Thicknesses: Ledyard, 26 ft.; Wanakah, 48 ft.; Tichenor, 1 ft.; Deep Run, 10 ft.; Menteth, 1 ft. Total thickness, 86 ft.

Collections were also made from exposures at Menteth Point and Tichenor Point on the west shore of Lake Canandaigua and from Deep Run Creek on the east shore of the lake. These collections are not described in this report.

Ohio: Silica shale: from exposures in the quarries of the Medusa Portland Cement Company near Sylvania, Lucas County. Total thickness, 18 ft. 7 in.

Ontario, Canada: Arkona shale and Hungry Hollow formations: from exposures on the Ausable River at Hungry Hollow (Marsh's Mill of the older reports), 2½ miles east of the village of Arkona.

Widder beds: from exposures in Rock Glen Creek near Arkona. Thicknesses: Widder beds, 36 ft. 6 in.; Hungry Hollow, 6 ft.; Arkona shale, 5 ft. (top). Total thickness, 47 ft. 6 in.

Complete suites of samples were collected and the stratigraphic position of each carefully determined. Except at contacts, samples were usually taken through intervals of three or five feet.

Laboratory procedure.—In the laboratory the shale samples were first reduced by washing and decanting. After most of the foreign material was removed in this manner, the samples were boiled for three or four hours in a sodium bicarbonate solution to break down the larger pieces of shale. After boiling, the samples were again washed and then spread out to dry. The clean dry residues were reduced further by screening. Nearly all of the ostracodes passed through the 1,000 micron screen, numerous specimens were retained on the 500 micron screen and the majority were less than 500 microns.

Repository.—All specimens obtained in this study have been deposited in the micropaleontology collection of the Department of Geology, Wayne University, Detroit, Michigan.

The majority of the ostracodes in the collection are typical Devonian forms. Fifty-three species have been identified of which six are new species.

PREVIOUS WORK

One of the earliest comprehensive reports on the stratigraphy of northwest Ohio is that of Stauffer (1909). For the upper Middle Devonian in northwest Ohio he used the Michigan term Traverse and considered the Ohio section as the southward outcropping of the Michigan strata. Although there was

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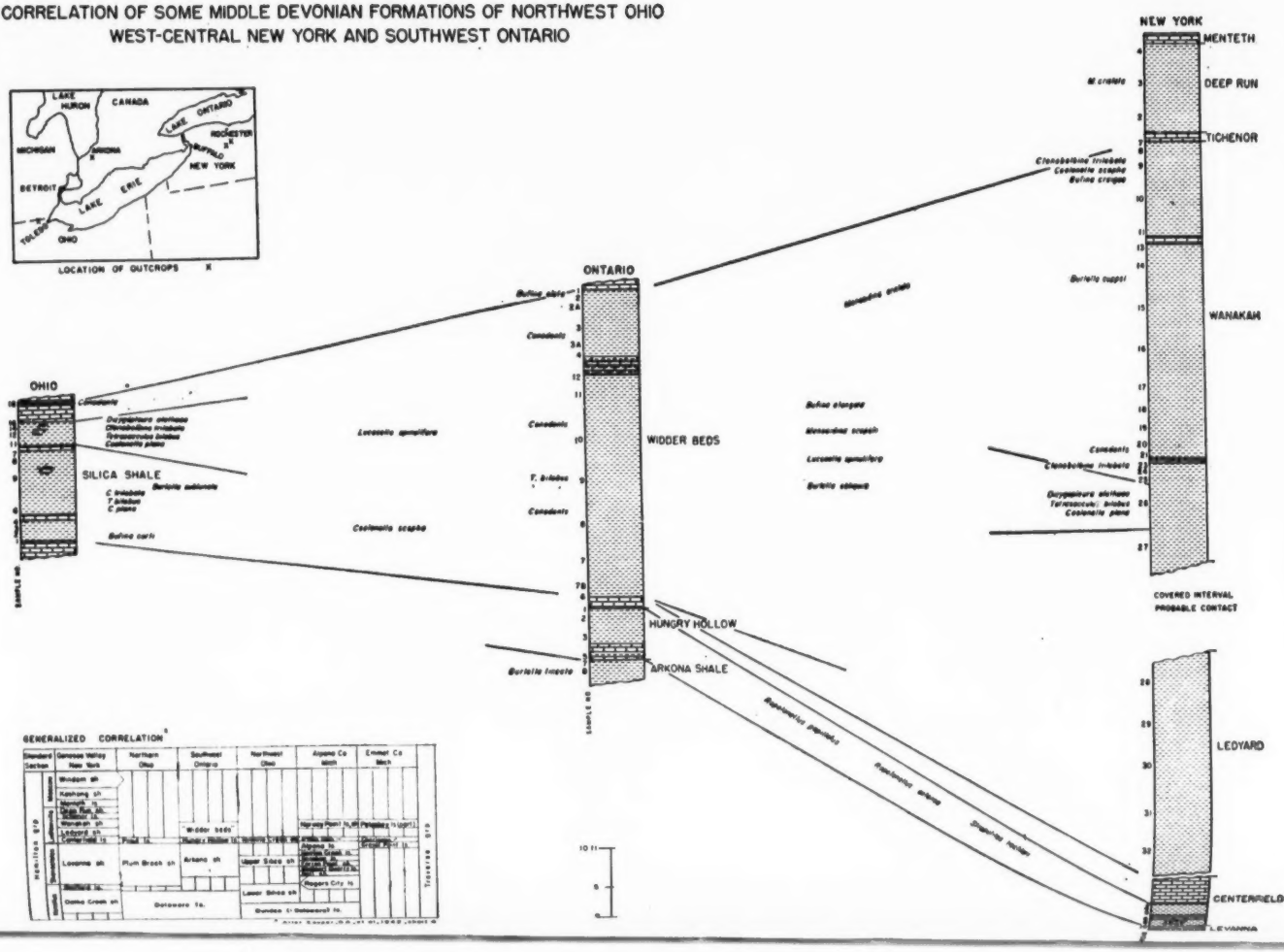
EXPLANATION OF PLATE 53

All figures approximately ×47.

FIG. *1*—*Bufina elongata* Coryell and Malkin. Left valve. (p. 463)
2—*Bufina curti* Coley, n. sp. Right valve. (p. 463)
3—*Bufina craigae* Coley, n. sp. Left valve. (p. 463)
4, 5—*Amphissites rowei* Coley, n. sp. *4*, left valve; *5*, dorsal view. (p. 462)
6—*Dizygopleura alethaae* Coley, n. sp. Right valve. (p. 462)
7–9—*Strepulites tischleri* Coley, n. sp. *7*, right valve; *8*, left valve; *9*, dorsal view. (p. 463)
10, 11—*Menoeidina scopeli* Coley, n. sp. *10*, right valve; *11*, dorsal view. (p. 462)
12—*Burlella obliquus* (Coryell and Malkin). Left valve. (p. 459)
13—*Burlella cuppsi* Coley, n. sp. Left valve. (p. 460)
14—*Burlella sublunata* Stewart. Left valve. (p. 460)

CORRELATION OF SOME MIDDLE DEVONIAN FORMATIONS OF NORTHWEST OHIO
WEST-CENTRAL NEW YORK AND SOUTHWEST ONTARIO



DISTRIBUTION OF OSTRACODE SPECIES

DISTRIBUTION OF OSTRACODE SPECIES

| SPECIES | NW OHIO | SW ONTARIO | | |

no attempt at a correlation with surrounding states, he did show a similar association of species, stating that over forty per cent of the northwest Ohio Hamilton fauna occurs at Thedford, Ontario (Stauffer, 1909, p. 184).

Stewart (1927) reported on the Silica shale as exposed in a quarry near the village of Silica, in northwest Ohio. Although she prepared a table showing the stratigraphic relationship of some Silica shale fossils with those of New York and Ontario, she did not choose, at that time, to correlate the Silica shale with any particular part of the Hamilton in New York or Ontario.

Stewart's paper, in 1936, on the ostracodes of the Silica shale showed zonal distribution and comparison with the ostracodes of the Traverse group of Michigan, but no attempt at a correlation with other localities was made.

Very little work has been done on the correlation of the Middle Devonian of Ontario with that of other localities. Stauffer's (1915) report on the Devonian of southwestern Ontario is a rather complete work, but no definite correlations with sections in New York or Ohio were made.

The most complete work on the Hamilton of New York was done by Cooper (1930, 1933). Although he correlated the outcrops exposed in New York, no attempt was made to correlate them with the sections under consideration in this paper.

Cooper et al. (1942) is among the most recent and comprehensive reports summarizing the correlation of the Middle Devonian of this area. The Arkona shale of Ontario is correlated with the Levanna shale of New York. Both formations are considered upper Skaneateles. The Hungry Hollow member, which lies above the Arkona shale and represents the basal member of the Widder beds in southwestern Ontario, is correlated with the Centerfield formation, which is basal Ludlowville of New York. The Widder beds lying above the Hungry Hollow member are indicated as being equal to the Ledyard formation of New York. Cooper et al. believe that the Silica section "covers a fairly long time interval ranging from upper Marcellus to upper Skaneateles," but that its precise position in the Hamilton group is uncertain. These correlations are based on lithology and megafossils.

Ostracodes constitute one of the most important elements of the Middle Devonian microfauna of this area. Before 1930, very little work, aside from describing the more typical species, was done on the Devonian ostracode fauna of Ohio, New York, and Ontario. The great abundance of ostracodes in the areas under consideration has been observed only recently, when Coryell and Malkin (1936) described a large number of species from the Widder beds at Arkona, Ontario, and when Stewart (1936) reported on the ostracodes of the Silica shale of Ohio. There has been no comprehensive paper published on the ostracodes of the New York sections.

From a study of the literature, it seems that one of the principal problems in the stratigraphy of Ohio is the precise position of the Silica shale in the stratigraphic column.

The primary purpose of this paper is to determine what bearing the ostracode faunas will have on the present correlation and to afford a more complete stratigraphic record of ostracode distribution. It is hoped that the ostracodes cited in this paper will contribute materially to knowledge of the stratigraphic distribution of ostracodes and problems of taxonomy.

STRATIGRAPHY

The Centerfield formation of New York and the Hungry Hollow member of the Widder beds of Ontario, both basal Ludlowville, are separated from the underlying formations by a sharp change in lithology. The contact of the Centerfield and the underlying Levanna formation, at the type locality of the Centerfield (Centerfield, New York), is covered so that any evidence of an erosional period between the two is hidden. However, the change between the Hungry Hollow and the underlying Arkona shale near Arkona, Ontario, is marked by an obvious disconformity.

The Centerfield formation and the Hungry Hollow member are very similar in appearance. Both contain thin-bedded limestones and calcareous shales with abundant corals. The correlation between these two formations becomes more convincing when a comparison of their ostracode faunas is made. Both formations are characterized by

the occurrence of *Ropolonellus extensus* (Coryell and Malkin), *Ropolonellus papillatus* (Van Pelt), and *Strepulites tischleri*, n.sp. Although *Ropoponellus extensus* (Coryell and Malkin) and *Ropolonellus papillatus* (Van Pelt) have been reported in other areas, there is no recorded association of these three species in one formation. That these three species are associated in a restricted zone in both the Centerfield and Hungry Hollow lends strong support to the present correlation of these two horizons.

Heretofore the consensus relative to the position of the Silica shale has indicated that it occupies an interval ranging from upper Marcellus to upper Skaneateles. Many of these opinions have been based on a similarity of the fauna of the Silica shale with those of localities other than New York or Ontario.

Cooper et al. (1942), in placing the Silica shale in the Marcellus-Skaneateles time interval, cite a few genera of megafossils such as *Schizophoria*, *Cananotoechia*, and others, which are suggestive of the Ferron Point and perhaps the Genshaw of the Michigan sequence (equivalent to Skaneateles of New York). They also believe that because the fauna of the Mount Marion (Marcellus) of New York is similar to the Silica shale, particularly the abundance of the genus *Paraspirifer* in both formations, the Silica shale should be correlated with the upper Marcellus. The fact that they fail to make use of specific similarities tends to make this correlation a bit dubious.

Stewart and Hendrix (1945, p. 88) in their study of ostracodes of the Plum Brook shale in Erie County, Ohio, which Cooper (1930, p. 123) and Stumm (1942) correlate with the Levanna shale (Skaneateles) of New York, mention the similarity of ostracodes from Plum Brook and Silica. Species represented in both formations are:

Ulrichia conradi (Jones)
Punctoprimitia simplex Stewart
Dizygopleura trisinuata Van Pelt
Poloniella cingulata Warthin
Ponderodictya ohioensis (Stewart)
Ponderodictya unicornis (Van Pelt)

This faunal similarity is more obvious than real since many of the above mentioned species have been found to range from formations of Skaneateles to upper Ludlowville age with some forms reported from formations as high as upper Moscow. Such relatively long ranged and prolific ostracodes as *Ponderodictya punctulifera* Hall (=*P. unicornis* [Van Pelt]), and *Punctoprimitia simplex* Stewart, are obviously of little use in a detailed stratigraphic correlation.

Warthin (1934), in his work on the Traverse group of Michigan, reports the occurrence of the following species:

> *Monoceratina casei* Warthin, in the Norway Point (equivalent to part of Ludlowville of New York) and downward to the Ferron Point formation (1937, card 16) (equivalent to part of Skaneateles of New York).
>
> *Poloniella cingulata* Warthin, from the Gravel Point formation (Warthin, 1937, card 61).
>
> *Strepulites crescentiformis* (Van Pelt) and *Strepulites quadricostatus* (Van Pelt) which range from the Bell shale (equivalent to part of Skaneateles of New York) to the top of the Norway Point formation (Warthin, 1945, card 35, 41).

In the sections studied, *Monoceratina casei* Warthin was found only in the Widder beds of Ontario. However, it has been reported from the Wanakah formation of New York. Apparently this species is restricted to formations of Ludlowville age in New York and Ontario and, if so, may suggest a higher stratigraphic position for those Traverse formations in which it occurs.

Van Pelt (1933, p. 339) described *Ropolonellus papillatus* (Van Pelt) from the Bell shale of Michigan. It is present in the Hungry Hollow member of the Widder beds of Ontario, the Centerfield formation of New York, and has been reported from the Silica shale of Ohio. This suggests that both the Bell shale of Michigan and the Silica shale of Ohio could be at least as high as the Centerfield of New York.

Poloniella cingulata Warthin occurs in the Silica and Arkona shales and *Strepulites quadricostatus* (Van Pelt) is in the Silica shale. The writer observed *Strepulites crescentiformis* (Van Pelt) in the Widder beds and it has been reported from the Silica shale by Warthin (1945).

Turner's (1939) report on ostracodes from well samples of Hamilton age in southwestern Ontario lists a number of species which

are characteristic of other sections. Among those species reported by Turner are:

Boursella trilobata Turner
Burlella lineata (Turner)
Eukloedenella doverensis Turner
Lucasella mundula Stewart
Menoeidina arcuata Turner
Poloniella cingulata Warthin
Strepulites crescentiformis (Van Pelt)
Strepulites quadricostatus (Van Pelt)

Among those species not mentioned in a previous comparison are: *Burlella lineata* (Turner), which was found in the Arkona shale of Ontario, *Boursella trilobata* Turner and *Menoeidina arcuata* Turner, in the Wanakah formation of New York, *Eukloedenella doverensis* Turner, in the Silica shale of Ohio and the Centerfield formation of New York, and *Lucasella mundula* Stewart, in the Silica shale.

While it is true that some of the species such as *Poloniella cingulata* Warthin and *Lucasella mundula* Stewart are apparently restricted to formations which are now considered Skaneateles age, the majority of species seem to indicate a higher stratigraphic position.

It appears that insofar as all of the ostracodes mentioned are apparently restricted to formations which are now considered as being, or equal to, Ludlowville or lower, actually the formations are more closely related than previously thought.

The samples mentioned in this paper, other than the author's, do not represent complete suites of stratigraphic collections, so it seems that a determination of the stratigraphic range of the species is necessary before they can be of definite aid in determining the precise stratigraphic position of these sections.

The evidence, as it now stands, seems in favor of placing the Silica section of Ohio and the Bell shale of Michigan in the Ludlowville.

With the exception of the New York sections, all of the formations of Skaneateles and upper Marcellus age are underlain by thick limestones. The shale sections above the limestones are represented in New York by much thicker deposits than elsewhere. This implies that there may have been a westward replacement of shale by limestone at the base of the Hamilton-Traverse group.

The argument for this type of replacement would be considerably strengthened if the Silica shale of Ohio could be proven of Ludlowville age as has been suggested in the present writing. A comparison of the fauna of the Silica shale of Ohio and the Wanakah formation of New York offers some evidence that seems to strengthen this hypothesis.

In the Silica formation, there is a two foot section of shale characterized by the presence of *Dizygopleura alethaae*, n. sp. This species occurs at no other horizon in the Silica section. In the Wanakah formation, there is a five-foot section in which *Dizygopleura alethaae*, n. sp., occurs. Here again, it is restricted to a narrow horizon. In both areas, this zone is overlain by a thin limestone, followed by a shale which contains conodonts.

In comparing the Silica, Widder and Wanakah formations, we find a preponderance of *Lucasella spinulifera* Stewart which tends to support a Ludlowville age for the Silica shale insofar as this species has not been reported from formations lower in the stratigraphic column. To lend more support to this proposed correlation is the presence of *Ctenobolbina trilobata* Stewart in the Silica shale and Wanakah formation, *Tetrasacculus bilobus* Stewart in the Silica shale, Wanakah formation, and Widder beds, and two unnamed specimens in the Silica shale and the Widder beds. If the Hungry Hollow and Centerfield, which are basal Ludlowville, are included in the comparison, the similarity in ostracode assemblages becomes even more suggestive of a Ludlowville age for all of these sections.

A progressive development of the anterior spines is shown in *Bufina elongata* Coryell and Malkin, *Bufina curti*, n. sp., and *Bufina craigae*, n. sp. The spines of *B. elongata*, which were found in the Widder beds of Ontario and the Wanakah formation of New York, are well developed. The spines of *B. curti*, present in the Silica shale, are coalesced at the base while the spines of *B. craigae*, found in the Wanakah formation, have apparently grown together, forming a ridge.

If the progressive change shown by these species is a result of a time interval rather

than environment, it appears that the Widder beds would occupy a position in the lower or middle Ludlowville and that the Silica shale would be equal to a part of the Wanakah formation of middle Ludlowville age.

PALEONTOLOGY

General discussion.—Some of the faunas described in this and other relatively recent papers afford excellent means of studying the intraspecific variability of Devonian ostracodes. Any occurrence of a great number of ostracodes within a relatively thin stratum affords a rather large sample of a practically contemporaneous population. Even though groups or individuals within this population may show a certain variability, provided there are no appreciable gaps between the different forms, there seems to be little doubt that this group of individuals must usually be considered conspecific.

An extensive collection bearing fossils in an excellent state of preservation has permitted a good evaluation of the limits of variability of several of the species studied. A study of the interspecific and intraspecific relationships should be particularly significant since the material studied has been collected stratigraphically with complete suites of samples. A quantitative statistical analysis, to which the samples would readily lend themselves, would make this study doubly important. However, at the present, as there has been insufficient time for such an exhaustive research, this will be limited to a discussion of a few of the more obvious variations.

As a result of this study, the writer has concluded that frequently genera and species of Devonian ostracodes that have been based upon one or two often poorly preserved individuals and separated from other species on the basis of small differences, have little chance of being valid species. Another practice in which authors have apparently indulged is the erection of new species and genera on the basis of specimens from different geographic localities and geologic horizons without sufficiently exhaustive comparisons with previous descriptions.

A new genus or species has no practical value until the geologic range has been carefully worked out. Some authors, in their zealousness to name a new genus or species, overlook the fact that once the new generic or specific name has been introduced, it will remain in the literature regardless of validity. It is obvious that at any one time, there can be only one valid name for a species, although there may be several available names and even more occupied names. It is, therefore, a lamentable fact that we have a great many identical, or slightly variable, forms masquerading under a number of different names, making it an almost hopeless task to correctly work out their range and proper classification.

To account for the abundance of genera and species, one need only quote Weller (1949, p. 681), "From the paleontologist's point of view, a species is only a concept whose limits are determined by chance and personal opinion." The practical consequence of these considerations is that the writer has attempted to be conservative in describing new genera and species.

The ostracodes which are included in this chapter are classified in seven genera and ten species. Six new species are described.

SYSTEMATICS

Order OSTRACODA Latreille

Family BAIRDIIDAE Lienenklaus

Genus BURLELLA Coryell and Booth

Burlella CORYELL and BOOTH, 1933, Am. Midland Naturalist, vol. 15, p. 268.
Quasillites CORYELL and MALKIN, 1936, Am. Mus. Novitates, no. 891, p. 13.

BURLELLA OBLIQUUS (Coryell and Malkin)
Plate 53, figure 12

Quasillites obliquus CORYELL and MALKIN, 1936, Am. Mus. Novitates, no. 891, p. 13.

As a result of studying samples ranging in age from upper Skaneateles to upper Ludlowville, the writer is of the opinion that the genus *Quasillites* should be declared invalid, and consequently the family Quasillitidae is probably likewise invalid. In examining *Burlella sublunata* Stewart and *Burlella obliquus* (Coryell and Malkin), it was observed that the immature forms of both species are identical in shape and development. Collections from the Wanakah formation of New York showed a vertical gradation from typical *Burlella obliquus* (Coryell

and Malkin) to an intermediate form, *Burlella cuppsi*, n. sp., which closely resembles *Burlella sublunata* Stewart.

In view of this similarity of immature forms and the presence of intermediate species, the writer feels justified in referring *Quasilites obliquus* Coryell and Malkin to the genus *Burlella*.

Plesiotypes, Wayne University, Cat. No. T-50007.

BURLELLA CUPPSI Coley, n. sp.
Plate 53, figure 13

Carapace subovoid to subrhomboidal; hinge line straight, about five-sixths the length of the shell; right valve grooved for the reception of the left valve; ventral margin straight or slightly concave at mid-length. Right valve overlaps left with most pronounced overlap ventrally. Anterior end narrowly rounded dorsally; posterior end narrowly curved in the lower half, broadly curved with distinct backward swing in the dorsal half. A prominent median spot is developed on both valves. Anterior end of each valve marked by a U-shaped depression terminated ventrally by a strong spine and dorsally by a distinct swelling. Posterior end marked by a ridge-like swelling set well forward of the end. Surface of each valve, between the end swellings, marked by prominent longitudinal lines bifurcating along the crest of the convexity and diverging anteriorly. Rest of surface minutely granulose.

Length, 1.20 mm.; width, 0.62 mm.

Holotype, Wayne University, Cat. No. T-50009.

Type locality, Geneseo (Jacox Run) New York, (Wanakah formation) (Hamilton).

Remarks.—This species is evidently the same as that described by Stewart (1936) and referred to by her as the male form of *Burlella sublunata* Stewart. The author feels that this species is an intermediate form and should consequently be classified as a new species.

BURLELLA LINEATA (Turner)

Bufina lineata TURNER, 1939, Bull. Am. Paleontology, vol. 25, no. 88, p. 21, pl. 1. figs. 9, 12.

Carapace oblong to rectangular, dorsal margin straight, ventral margin straight or slightly concave; hinge about five-sixths the length of the shell. Cardinal extremities obtusely angular; both ends sloping backward at about 105 degrees from the horizontal. Posterior end of each valve marked by a ridge-like shoulder, thickest posteriorly and blending into the carapace a little anterior of the cardinal angle, both dorsally and ventrally. This ridge extends out as far as the posterior margin, and in dorsal view the ridge of each valve forms a V with the posterior valve overlap. Anterior to this ridge, there is developed a concave impression.

Anterior end of each valve marked by a U-shaped depression, terminated ventrally by a distinct and in some specimens extremely well developed spine pointing forward and dorsally by a less well developed spine or node.

Hinge and overlap well developed. Right valve larger than left and overlapping it all the way around; overlap greatest along the ventral margin. Surface of both valves marked by fine crescentic lines opening anteriorly. Great thickness central.

Length, 0.80 mm.; height, 0.48 mm.

Plesiotypes, Wayne University, Cat. No. T-50008.

Locality, Arkona, Ontario (Arkona shale), (Hamilton).

Remarks.—This species was first described by Turner but not only was it placed in the wrong genus but also in the wrong family (Thlipsuridae Jones). Upon careful examination, the affinities to the genus *Burlella* become obvious. The anterior spines are not developed in the manner of *Bufina*, whose spines are horn-like while those of *Burlella* are forward pointing, as in the described species. Anteriorly, there is developed the U-shaped depression characteristic of *Burlella*. The posterior ridge or shoulder of the described species does not resemble the type of ridge developed in *Bufina*. In the genotype for *Bufina* (Coryell and Malkin, 1936, p. 8), the ridge is sharp, well developed, with definite dorsal and ventral terminations. In the described specimen, the ridge seems to be a gradually developed swelling of the shell.

In view of these considerations, no hesitation is felt in referring this form to the genus *Burlella*.

Family CYTHERELLIDAE Sars, 1865

Genus PONDERODICTYA Coryell and Malkin, 1936

PONDERODICTYA PUNCTULIFERA (Hall), 1860

Leperditia punctulifera HALL, 1860, New York State Cab., 13th Ann. Report, p. 92.

Primitiopsis punctulifera JONES, 1890, Quart. Jour. Geol. Soc. London, 46, p. 9, pl. 2, figs. 7, 12, 13.

Cytherella? bispinulata STEWART, 1927, Ohio Geol. Survey, Bull. 32, 4th ser., p. 60, pl. 5, fig. 19.

Primitiopsis unicornis VAN PELT, 1933, Jour. Paleontology, vol. 7, p. 326, pl. 39, figs. 23–28.

Cytherellina punctulifera (Jones) WARTHIN, 1934, Mus. Paleontology, University of Michigan, Contr., vol. 4, pp. 222–223, pl. 1, figs. 24, 25,

Hamiltonella punctulifera (Hall) STEWART, 1936, Jour. Paleontology, vol. 10, pp. 756–757, pl. 102, figs. 1–5.

The writer believes that the species *Ponderodictya unicornis* (Van Pelt) and *Ponderodictya bispinulata* (Stewart) should be consolidated with *Ponderodictya punctulifera* (Hall) as originally erected by Hall.

The specimens of the present study fail to show any valid criteria for the formulation of two separate species. The principal difference, as set down by Coryell and Malkin, is that *Ponderodictya bispinulata* (Stewart) has two spines near the posterior end while *Ponderodictya unicornis* (Van Pelt) has only one spine.

In this work, specimens from the Hamilton of Ohio, New York, and Ontario were studied, and from these localities *Ponderodictya* of the following types were found:

1. One prominent spine and ridge on both valves.
2. One prominent spine on the right valve, a small node on the left valve, and a ridge on the right valve only.
3. Two spines on the right valve, a small node on the left valve and a ridge on the right valve only.
4. Very small node in place of spine and very weakly developed ridge on right valve only.
5. Two spines and ridge on both valves.
6. One spine on right valve and two spines on left valve.

All gradations in development, ranging from those with no apparent spines or ridges to those in which the spines and ridges are very prominent, were found.

Where only a few specimens are found in a sample, they may be any one of the variants listed. However, where large assemblages are found in a single sample, all or any number of the variants may be present.

From this, coupled with the fact that the internal structure shows no reflection of the spines or ridges, it becomes apparent that these differences do not show a progressive change, and therefore one species is represented.

It is the writer's opinion that the species *Ponderodictya bispinulata* (Stewart) and *Ponderodictya unicornis* (Van Pelt) should be declared junior synonyms.

Genus MENOEIDINA, Stewart 1936

Thrallella STEWART and HENDRIX. 1945, Jour. Paleontology, vol. 19, p. 111, pl. 12, fig. 19.

This genus was set up by Stewart in 1936 and is described as having a crescentic forward curving shoulder-like ridge present in the anterior fourth of each value. Right valve overlapping the left. In 1945, Stewart and Hendrix set up the genus *Thrallella* which they described as having a crescentic backward curving shoulder-like ridge in the posterior portion of each valve. Left valve overlapping the right. By the simple process of placing the ridge on different ends in *Menoeidina* and *Thrallella*, there is a consequent reversal in the valve overlap which seem to be the primary difference in these two genera. It is the writer's opinion that the genus *Thrallella* has been erected on an erroneous orientation.

In describing the following species, the genus *Thrallella* will be considered a junior synonym, and the orientation of *Menoeidina* will be reversed.

MENOEIDINA CRISTATA (Swartz and Oriel)

Thrallella cristata SWARTZ and ORIEL, 1948, Jour. Paleontology, vol. 22, p. 561, pl. 79, figs. 22–23.

The original description of *Menoeidina cristata* (Swartz and Oriel) should be amended to include those forms in which there is no definite order in arrangement of the pits and those whose entire surface is pitted.

Plesiotypes, Wayne University, Cat. No. T-50010.

Locality, Geneseo (Jacox Run), New York (Wanakah formation), (Hamilton).

MENOEIDINA SCOPELI Coley, n. sp.
Plate 53, figures 10, 11

Carapace small, reniform to subreniform in outline, dorsal margin gently convex, ventral margin slightly concave at mid-length; anterior end narrowly rounded, posterior end broadly rounded to blunt.

Valves equally convex, left valve overlapping right on all but postero-dorsal margin, ventral overlap greatest. Hinge line straight, left valve slightly grooved in the posterior part for reception of right valve; giving a channeled appearance in the posterior dorsal half. Near the posterior extremity of each valve a crescentic shoulder-like ridge stands out from the shell surface, reaching its most posterior position ventrally. Anterior edge of shoulder characteristically marked by a row of pits which follows the contour of the shoulder and in some specimens extends along the ventral margin forming a near right angle. Surface of valve slopes smoothly from the posterior ridge about four-fifths of the shell length. About one-fifth of the distance from the anterior end there is a small ridge curving posteriorly. Within this ridge is developed a slight concavity. Inner edge of ridge is marked by a row of pits which follows the contour of the ridge. The valves slope smoothly from the ridge to the anterior end. Surface smooth to minutely granulose.

Length, 0.60 mm.; height, 0.30 mm.

Holotype, Wayne University, Cat. No. T-50006.

Type locality, Arkona, Ontario (Widder beds), Hamilton.

Remarks.—This species also occurs in the Centerfield and Wanakah.

Family KIRKBYIDAE Ulrich and Bassler, 1906
Genus AMPHISSITES Girty, 1910
AMPHISSITES ROWEI Coley, n. sp.
Plate 53, figures 4, 5

Carapace sub-oblong, dorsal margin straight and slightly shorter than the greatest length; cardinal angles a little greater than ninety degrees and nearly equal. Ends rounded, posterior less so and with a slight backward swing. Left valve overlaps right. A narrow outer flange extends around the carapace, flush with the outer margins except on the postero-dorsal and antero-dorsal ends where it swings slightly toward the center. This flange is marked all the way around by a row of pits. Within this outer flange, there is developed a ridge which follows the outline of the carapace, narrowing at the cardinal angles and joining the outer flange at the dorsal margin. Within the inner ridge, there is developed, slightly dorsal to the median line, a horizontal bar which does not quite connect with the inner ridge. No nodes or sulci observed. Surface reticulate.

This form resembles *Amphissites girtyi* Knight but may easily be differentiated by complete inner ridge, the horizontal bar, and the absence of a central node.

Length, 0.73 mm.; height, 0.50 mm.

Holotype, Wayne University, Cat. No. T-50005.

Type locality, Geneseo (Jacox Run), New York (Wanakah formation) (Hamilton).

Family KLOEDENELLIDAE Ulrich and Bassler
Genus DIZYGOPLEURA Ulrich and Bassler, 1923
DIZYGOPLEURA ALETHAAE Coley, n. sp.
Plate 53, figure 6

Carapace oblong to subrectangular, a little thicker posteriorly than in front, dorsal margin of right valve with a low post-median hump; anterior margin broadly rounded, ventral margin straight or with a slight sinuosity in the anterio-median area. Posterior margin more sharply rounded as compared to the anterior margin; cardinal angles obtuse but sharp.

Surface of valves quadrilobate; anterior lobe set back from the anterior margin, crescentic, strongly elevated; anterior sulcus comparatively wide, deep, long, open dorsally but terminated just above the ventral margin; median sulcus narrow, deep, extending nearly halfway across the valve. Lower half of valve has a wider, more shallow sulcus. Median lobe and post-median lobe widest dorsally; posterior sulcus long, may or may not be terminated dorsally and ventrally; narrower than anterior sulcus; posterior lobe narrow, slightly straighter than anterior lobe. Ends and sulci pitted, rest of surface granulose.

Length, 0.47 mm.; height, 0.25 mm.

Holotype, Wayne University, Cat. No. T-50004.

Type locality, Sylvania, Ohio (Silica shale).

Remarks.—This species also occurs in the Wanakah formation of New York.

Family THLIPSURIDAE Jones
Genus BUFINA Coryell and Malkin, 1936
BUFINA CURTI Coley, n. sp.
Plate 53, figure 2

Right valve larger than left; carapace ovate, elongate; dorsal margin straight, ventral margin slightly convex; anterior end smoothly rounded, posterior end rounded with pronounced backward swing, beginning in the posterior one-third and sloping sharply to about the median line where it curves smoothly forward to the ventral margin. Surface ornamented by two blunt anterior spines, which coalesce at the base forming a slight shoulder, and a submarginal posterior ridge. Numerous tiny spines project from posterior and anterior margins. Greatest height located about one-third of the length from the posterior margin. Greatest length below the median line.

Length, 0.84 mm.; height, 0.50 mm.

Holotype, Wayne University, Cat. No. T-50003.

Type locality, Sylvania, Ohio (Silica shale).

Remarks.—This form was described by Stewart (1936) as *Moorea bicornuta* Ulrich. However, it does not belong in that genus or species.

Bufina curti Coley, n. sp., is similar to *Bufina elongata* Coryell and Malkin but differs principally in the joined anterior spines which produce a shoulder at the base of the spines.

BUFINA CRAIGAE Coley, n. sp.
Plate 53, figure 3

Right valve larger than left; carapace ovate, elongate; dorsal margin straight, ventral margin slightly concave centrally. Anterior cardinal angle gently obtuse; posterior cardinal angle more acute than anterior. Anterior end evenly rounded, posterior end rounded with pronounced backward swing, beginning in the posterior one-third and sloping sharply to about the median line, where it curves smoothly forward to the ventral margin. Surface ornamented by a submarginal anterior and posterior ridge; anterior ridge more shoulder-like. Numerous tiny spines projected from the posterior and anterior margins.

Length, 0.88 mm.; height, 0.50 mm.

Holotype, Wayne University, Cat. No. T-50002.

Type locality, Geneseo (Jacox Run), New York (Wanakah formation) (Hamilton).

Remarks.—The species *Bufina elongata* Coryell and Malkin, *Bufina curti* Coley, n. sp., and *Bufina craigae* Coley, n. sp., seem to show a progressive development of the anterior spines. The spines of *Bufina elongata* Coryell and Malkin are well developed, those of *Bufina curti* are coalesced at the base, while the spines of *Bufina craigae* have apparently grown together, forming a ridge. It is probable that *Bufina curti* represents an intermediate form.

Genus STREPULITES Coryell and Malkin, 1936
STREPULITES TISCHLERI Coley, n. sp.
Plate 53, figures 7–9

Valves reniform, unequal, right valve overlapping the left on the entire margin. Dorsal margin convex; ventral margin concave centrally becoming convex toward the ends; ends rounded. Ventral contact with slight central sinuosity. Hinge line slightly S-shaped, right valve grooved in posterodorsal half to receive smaller left valve.

Carapace ornamented by an anterior plateau-like shoulder. The bounding ridges of the plateau are abruptly elevated above the surface anteriorly and dorsally and grade into the surface level along the anterior ventral margin. Surface of valves marked by three longitudinal sulci. The dorsal sulcus opens at the base of the plateau anteriorly and extends posteriorly approximately seven-eighths the length of the shell, curving downward to the median line. The ventral sulcus is straight, nearly parallel to the ventral margin, terminating anteriorly at the edge of the plateau, and posteriorly just short of the dorsal sulcus. The median sulcus extends from edge of plateau to mid-length. Surface minutely granulose.

Length, 1.0 mm.; height, 0.63 mm.

Holotype, Wayne University, Cat. No. T-50001.

Type locality, Centerfield, New York (Centerfield formation), (Hamilton).

CONCLUSIONS

It is generally accepted that the sections studied for this report are, with the exception of the Silica shale of Ohio, of Ludlowville age. The Silica shale has been considered as equal to Skaneateles or Marcellus. The ostracode assemblages support the previous correlation of the New York and Ontario sections. Although many of the ostracodes present in the Silica shale are apparently restricted to formations which are now considered equivalent to Skaneateles time, the majority of species suggests a higher stratigraphic position for the Silica section. This is also believed to be true for the Bell shale of Michigan. The correlation of the Silica shale with the Wanakah formation (Ludlowville) of New York is strongly suggested by the occurrence of restricted species such as *Dizygopleura alethaae* Coley, n. sp.

A conclusion reached by the author is that there may have been a westward replacement of shale by limestone at the base of the Hamilton-Traverse group. If this hypothesis is true, it appears that both the Silica and Bell shale should be considered of Ludlowville age.

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A BIBLIOGRAPHY OF THE FAMILY FUSULINIDAE

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ABSTRACT—This bibliography encompasses 633 references pertaining to the family Fusulinidae and may be considered reasonably complete to the year 1952, inclusive.

WITH the great impetus in the fusulinid studies, especially by the major oil companies during the last twenty years, it has been thought desirable to compile a comprehensive list of all major fusulinid references so that a concise listing might be available to all workers in the field. Mention must be made of the excellent bibliographies by Dunbar and Henbest (1942, pp. 151–161) and Thompson (1948, pp. 98–102). However, during the last few years numerous additional papers have been published, and their inclusion in a more comprehensive listing is now desirable and necessary.

In addition to recording articles dealing entirely with descriptions, morphology, and taxonomy, those in which fusulinids were used or mentioned for correlative purposes are also included. Mere mention of fusulinid names in faunal lists or incidental occurrences did not warrant inclusion in this bibliography.

Numerous Russian publications have appeared during the last few years. The most significant are recorded below; however their availability and academic value might be seriously questioned.

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JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 4, PP. 485–488, 1 TEXT FIG., JULY, 1954

PALEONTOLOGICAL NOTES

NOTE ON A NEW SILURIAN (DOWNTONIAN) SCORPION FROM SHROPSHIRE, ENGLAND

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Silurian scorpions are generally considered to be our earliest record of air breathing or land dwelling animals. Possibly due to the nature of their habitat, Silurian scorpions are very seldom found. In total only four species are known, each of which is represented by a single specimen. These forms are *Palaeophonus nuncius* Thorell and Lindström from the Upper Silurian (Ludlow) of Gotland, *Palaeophonus caledonicus* Hunter from the Ludlow of Lanarkshire, Scotland, *Dolichophonus loudonensis* (Laurie) from the Wenlock beds of the Pentland Hills, Scotland, and *Proscorpius osborni* (Whitfield) from the Bertie waterlime at Waterville, New York. To our meagre knowledge of these rare fossils, we can add a new form, which although represented by only a fragment, is nevertheless of sufficient interest to merit recording. This new form is from the well known Downtonian beds at Ludford Lane, Ludlow, Shropshire, England, an area that has furnished many of our best known Eurypterida.

In a collection of Downtonian eurypterids, kindly sent to the writer by Dr. C. J. Stubblefield of the Geological Survey and Museum (London), was a small specimen which proved to be the chela of a small scorpion. The specimen, consisting of a complete chela, or hand, had been previously figured and described by Salter (1859, p. 235) as the chelicerae of an eurypterid, and was found in a small slab of alternating green shales and very ill-sorted, coarse, sandstone, approaching a conglomerate in texture. The chela lies within the shale parting directly over- and underlain by the coarse conglomeritic sandstone which contained numerous black fragments that appear to be macerated fish plates. The chela is well preserved and retains convexity.

The writer takes pleasure in naming this rare fossil after the late Mr. Robert Lightbody, of Ludlow, Shropshire, England, who collected this specimen in 1858 or 1859 and who was responsible for many important, early collections of Eurypterida and other fossils in the Ludlow area.

Order SCORPIONES
Suborder PROTOSCORPIONES
Family PALAEOPHONIDAE
Genus PALAEOPHONUS Thorell and Lindström, 1885
PALAEOPHONUS LIGHTBODYI
Kjellesvig-Waering, n. sp.

Eurypterus? possibly *pygmaea* SALTER, 1859, Quart. Jour. Geol. Soc., London, vol. 15, p. 235, pl. 10, fig. 20.

Chela, relatively slender; hand straight along inner margin, curved at both extremities; outer edge, including fixed ramus, forms a gently incurving arch, greatest width slightly anterior to the point of attachment of the free ramus. Fixed ramus, longer than other. Each tapers inward to form, along the inner margins, a rather thin edge. Free ramus straight on outer edge and gently curved along inner edge.

FIG. 1—Chela of *Palaeophonus lightbodyi*, n. sp. ×4.

Greatest length, 10.0 mm; greatest width, 3.6 mm.

Depository.—Registered under no. 89424 in the Geological Survey and Museum, London, England.

Remarks.—In comparison to *Palaeophonus nuncius* Thorell and Lindström and *Palaeophonus caledonicus* Hunter the general outline and slenderer aspect of the chela

of *P. lightbodyi* serve as the main differences.

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AN ANALYSIS OF THE METHODS OF STORING INVERTEBRATE FOSSILS

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There is no perfect way of storing fossils. A method that is satisfactory for one individual or museum will be found impractical for another. An attempt has been made to survey some of the important museums and universities in this country and abroad to determine the methods used to store their invertebrate fossils. Consideration was given to the scope and special needs of the various collections. The two main methods are stratigraphic and systematic with various sub-headings of each.

An analysis of the answers shows a strong preference for the stratigraphic method of storing the fossils, especially on the part of those museums primarily devoted to research. When an institution is engaged in teaching, it is frequently found desirable to maintain two separate collections, one filed stratigraphically and the other systematically, the emphasis depending upon whether the teaching stresses systematic or stratigraphic paleontology.

In many cases the institutions prefer to arrange their material first under formation or some other stratigraphic unit, and then to sort the fossils systematically under the stratigraphic unit. Larger museums prefer two separate collections, while many universities prefer their general collection to be stored stratigraphically with a special systematic collection for classes in paleontology.

To date 108 replies have been received, including 82 from the United States and Canada and 26 from foreign countries. The accompanying table summarizes these replies.

INSTITUTIONS DEVOTED PRIMARILY TO TEACHING

a. Systematic method only	4
b. Systematic method mainly	6
c. Stratigraphic method only	4
d. Stratigraphic method mainly	4
e. Both methods	12

INSTITUTIONS DEVOTED PRIMARILY TO RESEARCH

a. Systematic method only	1
b. Systematic method mainly	4
c. Stratigraphic method only	16
d. Stratigraphic method mainly	10
e. Both methods	9

INSTITUTIONS DEVOTED TO BOTH TEACHING AND RESEARCH

a. Systematic method only	0
b. Systematic method mainly	4
c. Stratigraphic method only	9
d. Stratigraphic method mainly	7
e. Both methods	13
No collection	5
	108

SUMMARY

Mainly systematic	19
Mainly stratigraphic	50
Both	34
No collection	5
	108

A NEW BLANCAN VERTEBRATE LOCALITY

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In 1953 Professor Jack T. Hughes of the West Texas State College guided a University of California Museum of Paleontology field party to a previously unrecorded fossil vertebrate locality in Deaf Smith County, Texas. This site is 3½ miles east-northeast of the town of Hereford and is ½ mile southeast of the trash disposal dump for that community. The fossiliferous deposits are exposed in the large drainage ditch which has been excavated between U.S. Highway 60 and the Santa Fe Railroad tracks; they consist chiefly of friable white to buff-colored sandstone beds filled with calcareous nodules and tubules. Fossils are confined to a 2-foot thick stratum. The lateral extent of these peculiar beds is only a few yards in all directions and they are believed to be a very localized spring-bog deposit forming a minor part of the regional caliche-"caprock" complex. Much of the bone material is fragmentary and the bones appear to have been freshly broken just before or during deposition; hence, it may be presumed that the preserved bones represent animals who died or were trapped in the bog and were then trampled by survivors.

The fossils obtained include *Equus* (*Plesippus*) cf. *E.* (*P.*) *simplicidens* Cope, Proboscidea, Tayassuidae cf. *Platygonus* LeConte, Camelidae cf. *Gigantocamelus* Barbour and Schultz, and Testudinidae. No invertebrates or plants were discovered. These remains are here designated the *Hereford Dump local fauna* and are assigned a Blancan age, correlative with the Blanco fauna of Crosby County, Texas. Collections from the locality have been made by the Panhandle Plains Historical Museum of Canyon, Texas, the University of California and the Frick Laboratories of the American Museum of Natural Nistory, New York, N.Y.

THE VALUE OF A DIAGNOSIS IN SYSTEMATIC PALEONTOLOGY

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A study of the various articles contained in the Journal of Paleontology during recent years reveals that only in a very few cases have authors included a diagnosis in descriptions of new species. Although not required in the International Code of Zoological Nomenclature, a diagnosis, correctly used, can be of the greatest value in paleontological studies.

The diagnosis, in this restricted sense, represents a statement of those characters which serve to distinguish a particular species from all others previously described. It contains, therefore, *selected* items from the description of the new species, but it is not simply a condensed and abbreviated version of the description. The description includes a comprehensive account of the characters of the species, but the diagnosis includes only those definitive characters which identify this species, and which differentiate it from others. The characters included in the diagnosis will not necessarily be the most important of those included in the description, but will represent a "key" by which the species may be identified. Such a diagnosis can be made both brief and comprehensive by the inclusion within it of the name of the genus to which the species is referred, in order to give a broad delimitation. A small number of authors include such a diagnosis in general sections headed "remarks" or "discussion," accompanying the description. There is no objection to this, although it may be preferable to retain such "remarks" for a discussion of the

affinities of the species. The number of authors who give any such diagnosis is, however, small, and the present author believes that the encouragement of the use of a diagnosis, as a definite item in systematic paleontology, would result in its more widespread adoption.

The value of the diagnosis is twofold. Firstly it provides a reliable and ready means of determining the affinities of any given specimen. In the absence of a diagnosis, a paleontologist has to decide for himself the distinctive characteristics of a species which has been described by another author. The use of a diagnosis by the original author of the species offers a far more reliable and rapid guide to its characteristic features. Secondly the use of a diagnosis would tend to discourage the erection of new species, without adequate reference to existing descriptions, and thereby reduce the consequent problems of synonymy. It is sometimes difficult to distinguish between either the illustrations or the descriptions of two specimens which have been described as different species. The availability of an original diagnosis would facilitate the determination of synonymy.

Another commendable practice, which is seldom followed in papers published in the Journal of Paleontology, is a statement of the material upon which a new species is erected. Such a statement was useful even during the now obsolescent typological concept of species, insomuch that it gave some indication of the extent to which variation had been studied. With the increase in consciousness of the importance of adequate sampling, and the value of studies of populations, it becomes even more desirable that a statement of the available material should be included in paleontological descriptions.

If adopted, these suggestions would greatly facilitate future paleontological research. A suggested outline for systematic descriptions would then include:

Name
Reference to plate and figure numbers
Synonymy
Diagnosis
Description
Dimensions
Material
Designation of type specimens, with catalogue numbers
Occurrence: (Localities and horizons, stratigraphical range where known)
Remarks.

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NOMENCLATURAL NOTES

NOMENCLATURE OF FAMILIES AND SUPERFAMILIES

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W. J. Arkell (Jour. Paleontology, vol. 28, p. 218, has recently attacked clause 54 (1) (a) of the "Copenhagen Decisions on Zoological Nomenclature," which provides that a change in the name of a type genus because of synonymy, whether objective or subjective, will not necessitate a change in any family-group name founded upon it. The purpose of this decision was to provide greater stability and continuity to names of the family group, especially those of families and superfamilies that are of wide and general usefulness and importance. It is accordingly surprising to find such a worthwhile provision so vehemently opposed. If indeed the decision would produce "unhappy effects" and "completely unfamiliar monstrosities," and if it would result in a "discreditable hunt . . . to be the first to unearth these corpses [junior synonyms] for revival," I am sure that those of us who warmly supported it at Copenhagen would join Dr. Arkell in denouncing it. But it seems clear that Dr. Arkell has misread the decision and has misjudged its effects. It is to be hoped that his forceful language has not prejudiced the case.

(1) The Copenhagen decision actually reads "where the name of the type genus . . . has to be changed because it is found to be . . . [a junior synonym]," and not, as Dr. Arkell gives it, where it "*has been* changed because it is. . . . " His fears of the ghosts of long-buried junior synonyms are understandable if one begins with his verb tenses, but *not* with those adopted at the Congress. Clause 54(1) (a) as it stands is specifically designed to avoid changes *in the future*. A procedure that can be applied to the past is given in clause 45, which Dr. Arkell does not mention.

(2) Under the old Code, when the type genus was found to be a junior synonym *both* generic and group names had to be changed, including those of tribe, subfamily, family, and superfamily, if all were involved. Changes in at least the higher group names usually had wide repercussions in unfamiliarity and inconvenience in collateral fields and in teaching. Under the Copenhagen plan, when such synonymy occurs, the rule will not require any changes of family-group names. This will give consequent advantages in stability, continuity, and familiarity. Under Dr. Arkell's proposal, however, we would revert to the old Code, under which changes would be required in those cases. We would be forced in the future to change family-group names to those new and hence "completely unfamiliar" group names which he himself dislikes. Furthermore, in cases of subjective synonymy, we might have to change names frequently, in keeping pace with changing subjective views of authors.

(3) Even if Dr. Arkell's interpretation were correct, authors who wished to avoid exhuming old group names based on long-buried junior synonyms would have only to maintain current usage while following the procedure provided in clause 45. Surely it is a mistake to lift clause 54 (1) (a) out of the plan and criticize it without relation to other provisions, especially those of clauses 45 and 54 (2).

(4) It should be noted that the views of Dr. Arkell, and also those of Dr. R. C. Moore, the leader of the Treatise of Paleontology currently in progress, were published in the Bulletin of Zoological Nomenclature prior to the Copenhagen meeting, along with many other expressions of opinion and arguments pro and con. All of these were before the Copenhagen Colloquium, which considered the problem in detail and recommended the plan on family-group names to the Commission and thence to the Section on Nomenclature and the Congress. Paleon-

tologists were represented at all stages, and the views of Arkell, Moore, and others were known and their viewpoints argued. There was, of course, difference of opinion on this point, as there was on many points. But the decision in clause 54 (1) (a) was arrived at by the substantial majority of 20 to 8 after lengthy discussion of the advantages and disadvantages, on the first and least hurried day of the Colloquium, and under the best circumstances in which nomenclatural decisions have ever been taken.

In England, more than 25 years ago, the British National Committee on Entomological Nomenclature formally proposed that a family name was not to be changed unless it or the name of its type genus was found to be a homonym. That Committee included such well known zoologists as Karl Jordan, S. A. Neave, and G. A. K. Marshall. Support for this solution of the problem has been growing in the last decade, and those who now wish to repeal it should realize the large amount of opinion on the other side. In the Bulletin of Zoological Nomenclature for July, 1953 (vol. 8, nos. 6/9), in which were published the views of Arkell and Moore, there are a number of statements in favor of *not* changing family names in cases of generic synonymy. The proposition of not changing was supported by several groups which gave special consideration to the major problems to come before the Copenhagen Congress—namely, the Nomenclature Committee of the Society of Systematic Zoology (W. I. Follett, Chairman; six out of eight members clearly expressing support), the American Committee on Entomological Nomenclature (C. D. Michener, Chairman), the Committee on Nomenclature of the American Museum of Natural History (John T. Zimmer, Chairman), and the Nomenclature Discussion Group of Washington, D. C. (R. E. Blackwelder, Secretary; approved by nearly 2 to 1 majority). Paleontologists are represented in three of those four groups. In a specialized field, the insect order Diptera, a questionnaire sent to dipterists all over the world in 1952 showed 69 percent of 166 votes in favor of the solution as later adopted at Copenhagen. It thus appears that the Copenhagen vote was a fair sample of the views of zoologists.

(5) In the long view, if a great proportion of animal species remains to be discovered and named (estimates for neozoology alone range from 50 to 90 percent), the number of generic and group names yet to be proposed and shuffled about with successive classifications and reclassifications will be considerable. Any rule that will render some name changing unnecessary for the future, as does clause 54 (1) (a), will be a great boon and should not be discarded.

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BOOK REVIEWS

AMERICAN TRIASSIC COILED NAUTILOIDS, A STUDY OF THE CLASSIFICATION AND EVOLUTION OF LATE PALEOZOIC AND EARLY MESOZOIC CEPHALOPODS, AND DESCRIPTIONS OF NEW SPECIES, by Bernhard Kummel. U.S. Geol. Surv. Prof. Pap. 250, 1953; 104 pp., 43 figs., 19 pls. $1.25 (paper cover).

This study consists basically of systematic descriptions and illustrations of the more than thirty species (12 of which are new) of nautiliconic cephalopods known from the Triassic of North America, but its scope is much broader. That is, it includes "an attempt to review the status and phylogenetic relationships of late Paleozoic and Triassic (coiled) nautiloids," and it contains discussions of each of the genera and families involved. These fossils are not common in the American Triassic, and the report being reviewed was based on all the specimens that have been accumulated by the United States Geological Survey in this country and Alaska, and especially on those found by the author during a decade of periodic study of the Triassic stratigraphy and paleontology in the Middle Rockies. Furthermore, a year was spent at the British Museum of Natural History where extensive collections from all over the world are housed and where there is a wealth of material from the region of the Tethyian geosyncline, in which Triassic cephalopods are relatively abundant.

The major conclusions of the report are ably summarized in the following excerpt from its abstract: "Of the nine families of late Paleozoic nautiloids three (of the coiled forms) are directly involved in the ancestry of Triassic nautiloids. Two of these 'Paleozoic' families include Triassic genera. Only three families of nautiloids are confined to the Triassic. Pennsylvanian, Permian, and Triassic nautiloids are very closely related and show no big breaks in their history. There is a large change in the evolutionary pattern of nautiloids between the Triassic and the Jurassic but only a very minor one at the Permian-Triassic boundary. Evolution of the nautiloids in the Triassic is mostly one of culminating patterns and modes started in the late Paleozoic."

The relationships and the limits of the genera are based on all of the available data, and in many cases more significance is attributed to the shape of the cross section than to the surface ornamentation. This feature is more difficult to use than might be thought, for almost all of the specimens are more or less distorted. Late Paleozoic and Triassic nautilicones are all constructed on a much more nearly uniform pattern than are early Paleozoic cephalopods. Nevertheless, in detail they reveal so much individual variation as to dismay most students. Therefore, it is not surprising that the author of the present report differs materially from previous workers in the generic placement of a good many species. That is, when assigning species to genera, one has to decide which of the ascertainable characters are the more important, and then try to be consistent; the former is strictly a matter of opinion, and the latter is more easily said than done.

The plates of this report are collotype reproductions of unretouched photographs (or of copies of illustrations published by previous workers), and they are uniformly good. The text is interspersed with a large number of cross sections and suture drawings, and there is a variety of charts and diagrams elucidating particularly the inferred phylogenies and the stratigraphic distribution of the late Paleozoic and the Triassic nautilicones. The volume is closed with an extensive bibliography and a thorough index. As is customary with publications of the U. S. Geological Survey, the paper, the printing, and the format are of the best. Clearly the report will long reflect credit on its author and publisher, and it will be welcomed by paleontologists everywhere.

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EVOLUTION AND HUMAN DESTINY by Fred Kohler, 1952. Pp. vi–120; 5½×7¾ in., cloth. Philosophical Library, 15 E. 40th

Street, New York (printed by Hallmark-Hubner Press, Inc.). Price $2.75.

In this small, interesting, well-written book author Kohler attempts "to synthesize certain presently known, but heretofore uncorrelated facts, phenomena and relationships into a self-consistent unifying structure" (p. 8) dealing with the evolution of human matter in general and the development of man and human society in particular. The object of his efforts is to establish a more unified concept of the evolutionary process.

The book consists of an introduction, outlining the author's purpose; eight chapters; and a selected bibliography. Subjects treated in the various chapters are, in order, pre-organic evolution and the problem of organization of matter, the most primitive forms of life, biological death and sexual reproduction, multicellular organisms, the societal organism, characteristics of human colony formation, human destiny and evolution, and an epilogue, in which suggestion is made of eventual integration of societal organisms into a "super-societal organism" (p. 15), and the development of a conscious universe. Aspects of Mr. Kohler's book should interest all biologists and geologists, as well as anthropologists and sociologists.

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FOSSIL PLANTS OF THE FLORISSANT BEDS, COLORADO. Harry D. MacGinitie, Carnegie Institution of Washington Publication 599, 1953, octavo, iii plus 198 pp., 75 plates, 1 figure. $5.25 cloth bound, $2.75 paper bound.

This very excellent analysis of about 145 species from the famous Oligocene Florissant beds could well be utilized by all paleontologists and paleobotanists as an example of how to document fossil animals and plants.

Dr. MacGinitie appears to have covered ably all pertinent aspects of this flora and its geologic setting. It is indeed refreshing to have presented sections dealing with the modern vegetation of the region, the geographic and geologic setting, the stratigraphy and structure of the strata, the composition and modern relationships of the fossil flora, and the age of the flora, prior to the usual, but necessary, systematic descriptions. The Oligocene environment is carefully reconstructed by comparison of the fossil plant community with modern communities and by consideration of the insect fauna and the chemical and physical character of the deposits containing the flora. It is visualized as a region of streamside and lakeside forest habitats in a piedmont of low relief to the east of the main Rocky Mountain uplift. The drainage is believed by the author to have been disorganized and partly ponded by successive volcanic outbursts which covered the area with dust, pumice, and mudflows resulting in the fossil fauna and flora being deposited in shallow, ephemeral lakes. The climate is envisioned as humid and warm temperate, not unlike the present climate of Monterrey, Nuevo Leon, Mexico. Warm winters and hot summers with abundant sunshine are indicated by the flora. The vegetation on the high ground, away from streamsides and lakesides, is thought to have been characterized by pines and evergreen oaks and to have been most probably of an open, scrub-forest type, with grass and microphyll shrubs in the drier areas.

MacGinities' philosophy of systematics is sound and encouraging, especially to the stratigrapher. Sections devoted to listing (1) synonyms and changes of name and (2) species rejected from the flora are useful and novel. One hundred and fourteen species (2 mosses, 5 herbs, 12 woody vines, 36 shrubs, and 59 trees) are listed systematically among 84 genera and 44 families. In addition, the author reports approximately 30 species of uncertain affinity, some of which are recognizable forms, of taxonomic validity, but of unknown relationships. Others are of doubtful value.

Good format and superior printing and illustrations combine with the excellent and thorough presentation to make this a desirable, informative, and useful scientific contribution.

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THE PERMIAN REEF COMPLEX OF THE GUADALUPE MOUNTAINS REGION, TEXAS AND NEW MEXICO; A STUDY IN PALEOECOLOGY by Norman D. Newell, J. Keith Rigby, Alfred G. Fischer, A. J. Whiteman, John E. Hickox, and John S. Bradley, 1953. W. H. Freeman & Co., San Francisco, Calif., 236 pp., 85 figures, 32 plates.

The Permian rocks of the Guadalupe Mountains of western Texas and southeastern New Mexico have been studied by many investigators during the past half century, and intensively studied since 1927, when their significance in relation to the oil deposits farther east became apparent. The reef origin of many of the Permian limestones of the area has been accepted for many years. One might well ask, therefore, whether a new study could be worth while. It must be remembered, however, that most of the previous studies were made primarily to clarify local problems and local stratigraphy, that critical observations had not been made on the details of sedimentation and ecology, and that comparisons were lacking, both with modern deposits in similar environments and with comparable fossil deposits elsewhere in the world.

The present study, sponsored by the American Museum of Natural History and Columbia University, with the aid of research funds granted by the Humble Oil Company, builds on the accumulated lore of the earlier work to fill this gap in our knowledge. A research team of six investigators and six field assistants, organized and directed by Norman D. Newell, devoted three field seasons of detailed study in the field, and had at its disposal the facilities of the three sponsoring organizations in working up the results. The product is a commendable example of team research and of enlightened oil company policy, and its appearance in published form only five years after the inception of the project sets a goal worthy of emulation by other research workers.

The report deals not only with the well-known barrier reef of the Capitan limestone but also with its precursors, the smaller barrier reef of the Goat Seep limestone, and the patch reefs and limestone banks of the lower part of the Guadalupe series and of the Leonard series; it deals as well with the deposits laid down on one side in the deep waters of the Delaware Basin and on the other in the shallow waters of the shelf; it treats authoritatively the diagenesis of these deposits and the paleoecology of the marine animals and plants that lived there. A final brief but suggestive chapter speculates on the occurrence and origin of the oil which is being produced from the buried parts of the reef complex.

Study and evaluation of the various sedimentary features and fossil associations as here presented make the work an outstanding contribution, not merely to the reef problem, but to sedimentation and ecology in general. For the Guadalupe-Delaware Mountain region is, indeed, a rewarding outdoor museum and laboratory of these features. Little of the geological obscurity which plagues the investigator in the rocks of most areas is here present—the rocks are well exposed and over areas wide enough to give a three-dimensional picture; they have been scarcely deformed; the controlling environmental conditions are obvious.

An organic reef consists of "in situ accretions of calcareous organic debris which is cemented and lithified in place about as rapidly as it is deposited" (p. 105); this forms "solid structures that grow upward and outward against wave erosion" (p. 95). "The organisms most active in the building of reefs are encrusting forms that bind and cement loose material into a solid frame, which is, perhaps, the most distinctive characteristic of reefs" (p. 110). "Although many geologists have agreed upon the reef origin of the Capitan, few have recognized that the inclined beds are not part of the reef but constitute a talus apron built forward in comparatively deep water. . . . Hence the Capitan formation consists of reef limestone above and reef talus below" (p. 37). "The detrital deposits shed around a reef cannot properly be considered part of the reef any more than arkose fans are part of a granite massif from which they are derived" (p. 105).

In the text and diagrams one notes inconsistency in the definition of the term Capitan; in places the Capitan is defined as above quoted, to include both reef and talus; in others the named fore-reef units

are extended up through the talus to the edge of the reef. In view of the similarity in rock character between reef and talus, despite differences in origin, and the great dissimilarity of rock character between talus and fore-reef units, the first definition is certainly preferable.

"Living coral reefs are not characteristic of restricted basins and apparently do not occur near areas of bottom stagnation" (p. 12). Nevertheless, reefs of the Permian in the Guadalupe Mountains flank a deep stagnant basin, as do the most prominent other examples of fossil barrier reefs—those of the Triassic of the Tyrol, of the Permian of east Greenland, and of the Mississippian of northern England. "The association of reefs with stagnant basins can hardly be fortuitous" (p. 14).

"The Permian reefs of western Texas and southern New Mexico were formed by groups of organisms somewhat unlike those which are primarily responsible for living marine reefs, but nevertheless fossil and living reefs have much in common" (p. 199). The principal Permian reef builders were algae and sponges, and to a lesser extent bryozoans; the structures were not "coral reefs," as they have sometimes been called.

In view of the excellent discussion of the reefs in the text and the large amount of critical field work on which it is based, the reviewer is surprised at the crudity of the profiles through the Capitan reef presented in figures 52 and 58, in comparison with similar profiles previously published. It is true that a crude profile, if accurate, may illustrate a concept more clearly than a detailed profile, but important concepts are lost in the figures cited. The boundary between reef and backreef is shown as an ascending diagonal line, whereas backreef beds change into reef in groups of layers tens or hundreds of feet thick; the boundary between reef and backreef is steplike on a large scale.

In the description of the reefs and associated deposits one notes, without regret, the absence of the word "bioherm." The omission is deliberate, for as the authors say "a spade is not sharpened by calling it a geotome" (p. 11). Likewise omitted are the terms "euxinic" or "pontic" for the stagnant basin environment, "fondoform," "Clinoform," and "undaform" for basin floor, slope, and shelf, and all the geosynclinal jargon. For the only coined word used, "calcarenite," the reviewer agrees with the authors that no satisfactory English equivalent is available.

The writers are able to employ recent and fundamental results of oceanographic research, not available when earlier reports on the region were written. One finds, therefore, many deposits now ascribed to density currents, which hitherto were rather inexplicable. Also, present knowledge of the strength, or lack of strength, of newly deposited materials affords greater assurance than before of the penecontemporaneous deformation of sediments by gravity slides on surfaces of low declivity. The "giant cross-bedding" of the Bone Spring area becomes again a series of thrust slices, as it was believed to be by the first observer (Baker, 1920), and not a series of local unconformities as interpreted by most subsequent investigators. In general, this is probably correct, although plate 13, illustrating slump structures where "the glide surface simulates an unconformity" renews in the mind of the reviewer the old questions that existed in the Bone Spring area.

In the light of the detailed work and the new knowledge, many long-suspected ecological features are underscored and elaborated. Much of the prolific fauna of the limestone beds at the margins of the Delaware Basin is shown to have been winnowed and transported from the reef zone. "There are (sic) progressive attrition of shells basinward and selective elimination of the larger and most fragile forms. Securely attached reef forms, such as the encrusting algae, sycon sponges, *Leptodus*, *Prorichthofenia*, the productids, and massive bryozoans, are poorly represented in the detrital waste; there the recognizable fossils are chiefly pedunculate brachiopods, cryptostome bryozoans, and other weakly attached and fragile forms" (p. 194). To this reviewer, one of the most illuminating discussions is that on the habitat of the fusulines, and the subsequent distribution of their tests in the detrital waste—a matter on which he had always been uncertain.

It is also possible now to state with confidence what were the indigenous bottom-dwelling forms of the basin (leiorhynchoid

brachiopods, etc.), and what were the pelagic forms (radiolarians, ammonoids, etc.) that on death sank to the basin floor from higher levels.

One of the most original chapters in the book deals with diagenesis of the Capitan reef complex. Particularly interesting is the discussion of the origin of the chert and the silicified fossils—especially because of the marvelous preservation of the latter as revealed by the work of acid leaching being carried on by the U. S. National Museum and other organizations. It has been discovered that the Delaware Basin deposits contain abundant sponge spicules, originally siliceous but now calcified, indicating that large-scale exchanges of calcite and silica have taken place. Under low pH conditions, the silica is reprecipitated as nodules, plates, and crusts, or replaces originally calcitic or aragonitic shells embedded in the lower slopes of the reef talus.

Both the present work and previous publications on the region discuss the stratigraphy and rock character, and derive therefrom an interpretation of the geologic history. The present work differs from the earlier, however, in that the primary aim is interpretative rather than descriptive. The discussion is in terms of sedimentary structures and sedimentary environments, rather than being broken up according to a conventional stratigraphic outline. Much of the discussion, especially in the first half of the book, summarizes the previous work and conclusions on the area, with confirmation, and emendation by the authors, but in order not to interrupt the free flow of the text, the contributions made during the earlier and the present work are not differentiated. This desirable plan of presentation is marred by an over-meticulousness in refuting real or fancied errors by the earlier geologists, creating an impression that there is a greater divergence between the earlier and the present interpretations than actually exists.

At least some of the refutations arise from misinterpretation of the previous reports. It is stated that "King (1948, p. 85) believes there has been appreciable exaggeration of the original slopes of beds of reef talus" (p. 189), and a paragraph is devoted to proving that the angle of the talus slopes is the expectable one for such deposits. Yet reference to the page cited discloses only a discussion of the eastward and southeastward regional tilting of all the rocks of the area (late Permian to Tertiary), a factor recognized by the authors themselves in their reconstructions.

A more serious defect inherent in the plan of presentation is the lack of adequate documentation of the stratigraphic names. These have been proposed by many geologists in the past 50 years, during which time the names have undergone increasing elaboration. Some confusion might have been avoided by referring the reader to the last standard publication on the area, were it not that the table on page 15 indicates that the authors have also introduced stratigraphic names from other sources, and have made emendations and additions of their own. This table, and other parts of the book, show the following departures from previous usage, of which only those starred are explained even casually in the text:

"Lower Getaway" (member of Cherry Canyon formation)
"Upper Getaway"
Extension of term Getaway to lower part of former Goat Seep limestone*
"Shattuck" (member of Queen formation)*
"Lower (type) Hegler" (of Bell Canyon formation)
"Upper Hegler"
"McCombs" (member of Bell Canyon formation)
"Yates A, B, and C" (subdivisions of Yates formation)*

The McCombs member seemed especially enigmatic to this reviewer. Recourse to the index supplied only two page references, one bearing a chemical analysis of rock from the member, the other noting a fossil occurrence. In addition the reviewer counted eight other references of about the same nature (indicating, incidentally, the inadequacy of the index), but at no place a concise definition. The reviewer *supposes* that the McCombs is the same as the "flaggy limestone bed" of Professional Paper 215 (King, 1948, p. 57), but without a specific statement to that effect by the authors the term is a nomen nudum, and without legal standing.

The stratigraphic difficulties mentioned would have been done away with if a glos-

sary of stratigraphic names had been included, indicating when and by whom the names were defined, to what units they apply, and the emendations desired by the authors.

The work is copiously illustrated by text figures, and by 32 superb collotype plates, of which the most striking and novel are a set of 12 air photographs, in part taken by the authors themselves (hence more informative geologically than the hitherto available commercial photographs). The tables showing fossil distributions and ranges (figs. 80 to 85) condense into small space a vast amount of valuable and useful information on the paleontological stratigraphy of the Permian rocks of the region.

PHILIP B. KING
U. S. Geological Survey
Gatlinburg, Tennessee

JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 4, PP. 497–499, 2 TEXT FIGS., July, 1954

NEWS AND COMMENT

The Billings Geological Society of Billings, Montana, will hold its annual field conference, September 9, 10, and 11. Registration will be held in Billings, Montana, on Thursday, September 9, Friday and Saturday being devoted to a field trip through the northern part of the Big Horn Basin and through adjacent areas. Details for acquiring reservation blanks will be announced later.

A.G.I. NEWSLETTER

Chas. B. Hunt, executive director, American Geological Institute, 2101 Constitution Avenue, Washington 25, D. C., requests the following publicity about the institutes' publication, the Newsletter.

The Board of directors of the American Geological Institute, meeting at St. Louis, April 11, unanimously approved the plan to enlarge the Newsletter and send it to every member of the profession. The general plan is outlined in the April issue of the Newsletter.

Beginning with the September issue, the Newsletter will be sent to every person who is registered in the National Roster of Scientific and Technical Personnel (Earth Sciences). The address list for the Newsletter is being compiled from the register. We have more than 12,000 in hand but have reason to believe that about 5,000 are missing. Individuals who have not returned their A.G.I. Roster Questionnaires should do so if they wish to receive Volume VI of the Newsletter.

The April issue of the Newsletter states that the changes contemplated would increase the publication to 8 pages, printed on pulp paper, to be issued monthly 9 times a year. Pages 1, 2, and 3 would carry news stories. Page 3 would be a buffer page; page 4, editorial; pages 5–8, ads and filler (local meetings, titles of papers, campus corridors, industry notes, surveying the surveys, etc). There may be cartoons, 3–6 in each issue, caricatures of individuals (without attempting to compete with the Core-Driller).

Edward A. Koester, president of the Association, was the feature speaker at the meeting of the Kansas Geological Society, Wichita, May 11. His subject was "The Relationship of the American Association of Petroleum Geologists to the American Geological Institute."

The Gulf Coast Association of Geological Societies will hold its fourth annual meeting, November 3–5, at the Rice Hotel, Houston, Texas. Member societies who will be represented include the Baton Rouge Geological Society, Corpus Christi Geological Society, East Texas Geological Society, Houston Geological Society, Mississippi Geological Society, New Orleans Geological Society, Shreveport Geological Society, South Louisiana Geological Society, Lafayette Geological Society, South Texas Geological Society, and Southeastern Geological Society.

F. Alton Wade has resigned his position as professor of geology at Miami University, Oxford, Ohio, to accept the position as professor and head of the department of geology at Texas Technological College, Lubbock, Texas.

Henryk B. Stenzel has resigned from the University of Texas Bureau of Economic Geology at Austin to become chairman of the geology department at the University of Houston, effective September 1. He began his geological work with the Bureau in 1934 and became professor in the University of Texas in 1947. His future address is Geology Department, University of Houston, 3801 Cullen Boulevard, Houston 4, Texas.

Carey Croneis, head of the department of geology at the Rice Institute, Houston, Texas, spoke on "Problems of Geological Education," at the meeting of the Houston Geological Society on May 24.

On May 28, the Government of the Republic of China, presented Hubert G. Schenck with the Order of the Auspicious Star in recognition of his services as "Scientist, soldier, and diplomat," and especially in recognition of his services as director of the Foreign Operations Administration Mutual Security Mission to China from November, 1951, to March, 1954. He has

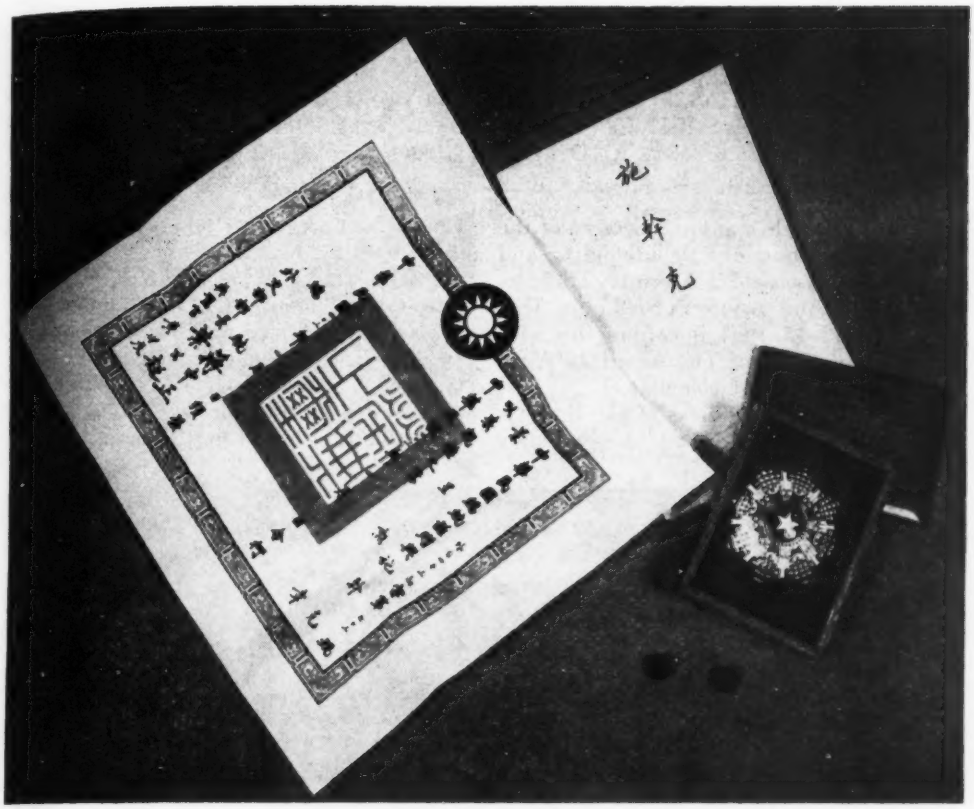
Present at the residence of Chinese Ambassador Wellington Koo in Washington, D. C. for the presentation of the Decoration of Ching Hsing (Auspicious Star) upon Hubert Gregory Schenck were (left to right): Ambassador Koo, Dr. Schenck, Mrs. Ingrid Schenck Beach, and Major General W. C. Chase, Chief, MAAG (Formosa).

returned to California (Box 1528, Stanford), and, although incapacitated, is serving as consultant to the Foreign Operations Administration on its programs in the Far East.

The Board of Natural Resources and Conservation of the Department of Registration and Education, State of Illinois, announces the retirement of Dr. M. M. Leighton, Chief, State Geological Survey, on July 1, 1954, after thirty-one years of service as Chief and thirty-five years as Geologist, and the appointment of his successor, Dr. John C. Frye, State Geologist and Executive Director, Kansas Geological Survey, and Professor of Geology, University of Kansas, Lawrence, Kansas.

J. J. Howard has been transferred from Creole Petroleum Corporation's Lagunillas, Venezuela office to the new Geological Exploration Laboratory, Maracaibo, Venezuela.

Clay mineral technology is the theme of the Third National Clay Minerals Conference to be held at the Rice Institute, Houston, Texas, October 27-28-29, 1954. The Conference is sponsored by the Clay Minerals Committee of the National Research Council. A special part of the program will be devoted to fundamental or applied papers. Anyone interested in presenting papers in *any* of these or *other* fields pertaining to clays or related minerals is invited to announce their intentions to A. F. Frederickson, Washington University, St. Louis 5, Missouri, on or before July 15, 1954.



Citation and Order of Ching Hsing (Auspicious Star) presented to Dr. Hubert Gregory Schenck.

A detailed program, including field-trip information, will be available on request in August, 1954. *Everyone* interested in any aspect of clay mineralogy, technology or related fields is cordially invited to attend the Conference.

JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 4, PP. 500–531; 4 TEXT FIGS., JULY, 1954

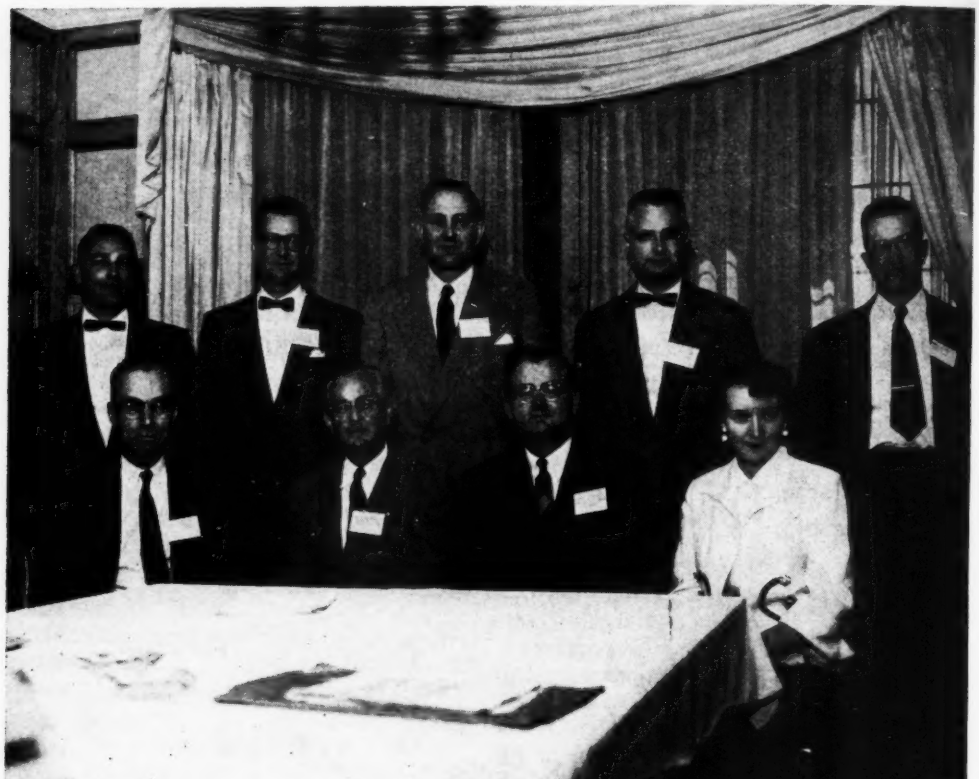
SOCIETY RECORDS AND ACTIVITIES

REPORTS AND MINUTES OF THE TWENTY-EIGHTH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The twenty-eighth annual meeting of the Society of Economic Paleontologists and Mineralogists was held in Assembly Hall No. 2 of the Kiel Auditorium in St. Louis, Missouri, April 12–15, 1954, in conjunction with the annual meeting of The American Association of Petroleum Geologists.

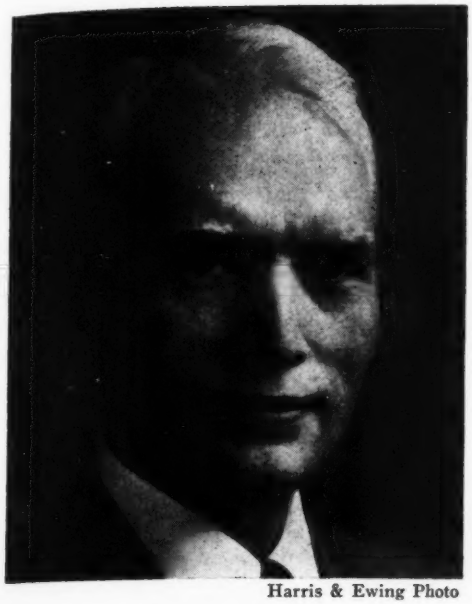
The Presidential Address of the Society, "The S.E.P.M. Looks Ahead," was given by Harold N. Fisk in the joint session on Tuesday, April 13.

Also in the joint session, Research Committee Chairman, E. C. Dapples, presented the Society's Award for the Best Paper for 1952 in the *Journal of Paleontology* to Lloyd G. Henbest, for his paper entitled "Significance of evolutionary explosions for diastrophic division of earth history," in the



S.E.P.M. OFFICERS 28th ANNUAL MEETING

Back row (left to right): W. T. Rothwell, Jr., *outgoing vice-president:* Grover E. Murray, *Editor—Paleontology:* Harold N. Fisk, *outgoing president:* Thomas H. Philpott, *outgoing 2nd past-president:* Robert H. Dott, *business manager, headquarters staff.*
Front row (left to right): Francis J. Pettijohn, *incoming vice-president:* Hans E. Thalmann, *incoming president;* Samuel P. Ellison, Jr., *secretary-treasurer;* Mrs. Nadine Jackson, *headquarters secretary.*



Harris & Ewing Photo

LLOYD G. HENBEST

May issue, Vol. 26, No. 3. R. Dana Russell accepted the Award for the Best Paper for 1952 in the *Journal of Sedimentary Petrology* on behalf of Ph. H. Kuenen and Henry W. Menard, Jr., for their paper entitled "Turbidity currents, graded and non-graded deposits," in the June issue, Vol. 22, No. 2.

S.E.P.M. BEST PAPER AWARD
28th Annual Meeting St. Louis, Mo.
April 12–15, 1954

Lloyd G. Henbest, U. S. Geological Survey, Washington, D. C., received the award for his paper entitled "Significance of evolutionary explosions for diastrophic division of earth history" published in the Society's bi-monthly *Journal of Paleontology*, Vol. 26, No. 3 (May, 1952).

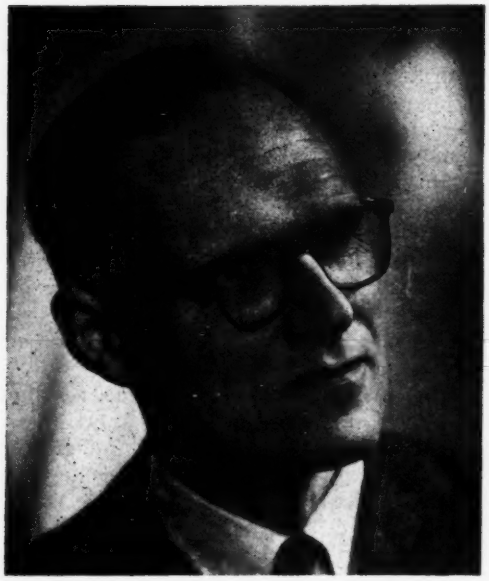
Philip H. Kuenen, Department of Geology, University of Groningen, Netherlands, and Henry W. Menard, Jr., Naval Electronics Laboratory, San Diego, California, received the award for their paper entitled "Turbidity currents, graded and non-graded deposits," published in the Society's quarterly *Journal of Sedimentary Petrology*, Vol. 22, No. 2 (June, 1952).

These Best Paper Awards are the first to be presented by the S.E.P.M. They consist of a certificate given to the author, or co-authors, whose paper, appearing in the Journals during the second preceding year, is judged by the Research Committee to be the most outstanding contribution of the year.

Formal presentation of the awards was made by Research Committee Chairman E. C. Dapples in St. Louis, Missouri, April 13, 1954, at the joint annual meeting of the American Association of Petroleum Geologists, Society of Exploration Geophysicists, and Society of Economic Paleontologists and Mineralogists.

Lloyd G, Henbest was born in Cassville, Missouri, in 1900, He attended the University of Arkansas, receiving a B.A. degree in 1924 and an M.A. degree in geology in 1926. He attended Yale University from 1928 to 1930. Henbest was an assistant instructor at the University of Kansas from 1924–1926, assistant geologist with the Illinois Geological Survey, 1925, 1926–30, and has been geologist-paleontologist with the U. S. Geological Survey since 1930. He is also custodian of the collections of Foraminifera in the U. S. National Museum. He was elected to membership in the S.E.P.M. in 1932, has been a member of the A.A.P.G. since 1931, is a past president of the Paleontological Society of Washington, a fellow of the Geological Society of America and the Paleontological Society of America. He also holds memberships in the A.A.A.S., the Biol. Photog. Assn., Geophysical Union, Washington Academy, and the Geological Society of Washington. His chief interests are micropaleontology, oceanography, Pennsylvanian and Permian stratigraphy, and photomicrographic technique. His hobby is pictorial photography and camera lens testing. In addition to his award-winning paper, he has had papers printed by the Illinois Geological Survey, in the American Journal of Science, the Illinois Academy of Science Trans., and the Journal of Paleontology.

Philip H. Kuenen was born in Dundee, Scotland, in 1902. He attended the University of Leyden, Netherlands, receiving a Ph.D. degree in 1925. Kuenen was a university assistant to Prof. B. G. Escher, at the University of Leyden from 1926–1934. During 1929–1930 he worked as geologist with the Snellius Expedition in the eastern part of



PHILIP H. KUENEN

U.S. Navy Photo

HENRY W. MENARD, JR.

the Netherlands East Indies. From 1934 to 1943 Dr. Kuenen was a lecturer in geology at the University of Groningen, Netherlands, and since 1943 has been a professor in geology at that University. He was elected to associate membership in the S.E.P.M. in 1951. He is also a member of the Royal Netherlands Academy of Science, an honorary foreign member of the Geological Society of London, and the Belgian Geological Society, a member of the Geological Association (Britain), and of the Geological Society of the Netherlands. He has written more than 80 papers which have been published in scientific periodicals and books.

Henry W. Menard, Jr., was born in Fresno, California, in 1920. He attended California Institute of Technology, Pasadena, California, receiving a B.S. degree in geology in 1942, and an M.S. degree in geology in 1947. He attended Harvard University from 1947–1949. Menard did field mapping for the Amerada Petroleum Corp., Los Angeles, California, during the summer of 1947, and since 1949 has been employed by the Naval Electronics Laboratory, San Diego, California. He was elected to associate membership in the S.E.P.M. in 1949, was vice-chairman of the Research Committee in 1951 and chairman of the committee in 1952. In addition to his award-winning paper, he has had several articles printed in the *Journal of Sedimentary Petrology*, one in the Southern California Acad. Sci. Bulletin, and was co-author of a paper printed in the S.E.P.M.'s special publication on turbidity currents, 1951.

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

28th ANNUAL MEETING

St. Louis, Missouri

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PROGRAM AND ABSTRACTS

Tuesday, April 13, 9:00 A.M.
Opera House, Kiel Auditorium

JOINT SESSION

PRESIDENTIAL ADDRESSES, HONORS, AND AWARDS

THE S.E.P.M. LOOKS AHEAD

HAROLD N. FISK

In the quarter century since its organization, the S.E.P.M. has proved its worth to the geological profession in many ways. The Society now forms one of the strongest ties between the economic and academic fields of geology. It stimulates research, offers a medium for exchange of ideas, and publishes journals of a high standard. These accomplishments reflect the value of its original objectives and the degree to which they have been met, and they indicate the future course to be pursued. To be of greatest service, the Society should conduct its affairs with as much independence as possible, and should make every effort to operate on a sound financial basis. It should increase its efforts to keep up with developments in stratigraphy and should strive to obtain the active participation of more paleontologists and petrologists by fostering the organization of regional sections. The Society will always require aggressive leadership, both at a central and regional level. To help assure this, the Research Committee is being expanded to be more representative of membership in the various sections of the country and will be given greater responsibility in the conduct of Society matters. Most of all, the Society must continue to encourage in every possible way the gathering and dissemination of stratigraphic information fundamental to our knowledge of the geology of petroleum.

Tuesday, April 13, 2:00 P.M.
Assembly Hall No. 2, Kiel Auditorium

MINERALOGY AND SEDIMENTARY PETROLOGY

Presiding: H. A. IRELAND, University of Kansas, Lawrence, Kansas AND D. H. EARGLE, U. S. Geological Survey, Austin, Texas

1. LOWER PENNSYLVANIAN SEDIMENT SOURCES OF THE EASTERN INTERIOR BASIN*

RAYMOND SIEVER AND PAUL E. POTTER
Illinois State Geological Survey, Urbana, Illinois

Knowledge of the source of sediments is one of the keystones of any study of the origin of a group of sediments. The establishment of locations and types of sediment sources and estimates of the relative amounts of detritus supplied by each source are necessary in the regional study of any group of clastic rocks. Provenance is also important in many studies for an understanding of environmental processes.

Cross-bedding direction and sedimentary petrography were used to assess the provenance of basal Pennsylvanian orthoquartzites in the Eastern Interior Basin. Over 900 cross-bedding measurements from the Eastern Interior and Michigan basins and portions of the Appalachian Basin in Ohio, Kentucky, and Tennessee were used in determining the regional pattern of direction of sediment transport. The cross-bedding direction of the basal sandstone is related to the youthful topography of the Mississippian-Pennsylvanian unconformity. Evidence suggests that *the direction of both crossbedding and pre-Pennsylvanian channels is consequent on the regional slope from the source area.* Because of its intracratonic position the Eastern Interior Basin received sediments from the northern Appalachians and from eastern and western parts of the Canadian Shield.

Petrography was also used to evaluate these contrasting sources of supply. Over 200 thin-sections, distributed approximately one to every 12 miles of outcrop, were examined. The results of this study indicate three regional mineral associations that, in general, correlate with contrasting cross-bedding directions.

The major area of subsidence and sedimentation in earliest Pennsylvanian time was to the south and southwest of the Eastern Interior Basin: this area gradually expanded and progressed northward to the interior of the Continent. As indicated in the Eastern Interior Basin and regionally, there was appreciable bypassing of sedimentary materials.

2. FACIES DEVELOPMENT AND INTERTONGUING IN THE BOOK CLIFFS OF EASTERN UTAH

ROBERT G. YOUNG
The California Company, Casper, Wyoming

Excellent exposures of Upper Cretaceous rocks in the Book Cliffs of eastern Utah exhibit complex intertonguing relations between four distinct facies. Rocks of the inland, lagoonal, and littoral marine facies of the Star Point and Blackhawk formations pass eastward into offshore deposits of the Mancos shale. These facies are present in a normal vertical and horizontal succession with some repetition due to the intertonguing produced by shifting environments. All these facies intertongue, but the most significant intertonguing is that between littoral marine standstones and offshore marine shales.

In the western end of the Book Cliffs the Star Point sandstone consists of three littoral marine sandstone tongues which disappear eastward into the Mancos shale. Resting on the upper tongue (Spring Canyon tongue) are about 100 feet of coal-bearing rocks comprising the Spring Canyon coal member of the Blackhawk formation. This member is separated from the overlying Aberdeen member by a thin tongue of Mancos shale. These coal-bearing rocks are terminated eastward by two offshore bar sandstones which appear near the town of Helper. The coal-bearing rocks of the overlying members of the Blackhawk likewise formed behind such barriers, and are seen to terminate seaward behind other bars. These bars appear as small littoral marine sandstone tongues which pass into the marine shale to the east. The primary difference between them and the larger littoral marine sandstone tongues, which occur at various horizons in the Star Point and Blackhawk formations, is their lesser areal extent. All are regressive sandstones formed during the progressive eastward retreat of the Upper Cretaceous shoreline following sharp pulses of basinal subsidence of various magnitudes. The larger tongues formed following the greater subsidences. These were usually separated by several subsidences of lesser magnitude.

After the formation of each sandstone tongue, long periods of quiet conditions prevailed before the next subsidence. This is indicated by thick coal deposits which rest directly on the sandstone tongues or lie at positions in the lagoonal deposits corresponding to the tops of the offshore bars.

3. THE PROCESS OF DEPOSITION OF THE SALINA SALT OF MICHIGAN

LOUIS F. DELLWIG
University of Kansas, Lawrence, Kansas

A comparison of the Salina salt of Michigan with solar salt and artificially produced grainer salt reveals similarities in the crystals which necessitate a parallelism of genesis. Additional information concerning the formation of bedded

* Published with permission of the Chief, Illinois State Geological Survey.

salt deposits is to be found in the petrographic examination of the so-called "jahresringe," and in temperature determinations in the liquid inclusions in the halite.

The accumulated evidence indicates that seasonal or temperature changes are recorded in the alternating bands of clear (inclusion-free) and cloudy (inclusion-rich hopper crystals) salt. The anhydrite and dolomite laminae (jahresringe) are indicative of an influx of sea water into the basin of deposition. Evaluation of the indicated temperatures of deposition obtained from the liquid inclusions points to deposition at lower temperatures than have been called for by many workers in the past.

4. A COMPARATIVE STUDY OF UPPER CHESTER AND LOWER PENNSYLVANIAN STRATIGRAPHIC VARIABILITY*

PAUL E. POTTER AND RAYMOND SIEVER
Illinois State Geological Survey, Urbana, Illinois

A fundamental property of sediments is stratigraphic variability, whose quantitative study is long overdue. For any stratigraphic parameter, the analysis of variance in which the variance at different levels of sampling is computed and compared provides estimates of variability for increasing increments of area. In this study the analysis of variance is used to compare the homogeneity of Upper Chester sandstones and limestones with that of Lower Pennsylvanian sandstones.

Seventy-two electric logs were chosen at random from a 2916 square mile area of the Illinois Basin largely devoid of contemporaneous tectonism, subdivided as follows:

2 wells per section
2 sections per township
2 townships per supertownship
9 "supertownships" (one supertownship = 3×3 land survey townships)

Maximum variability in Pennsylvanian sandstones is between townships, the order of variability being: Wells < sections < townships > supertownships. These values are compared with Upper Chester sandstones and limestones. For Pennsylvanian and Upper Chester sandstones local hydrodynamic factors are probably chiefly responsible for variability between wells, environmental factors for sections and townships, and tectonic factors for supertownships.

Quantitative studies of stratigraphic variability provide confidence limits for various stratigraphic parameters. An example would be how accurately a given number of wells sample a section, a township, or a supertownship. Quantitative studies of stratigraphic variability have significance for correlation, for environmental and tectonic interpretation, and sedimentary differentiation.

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5. STATISTICAL ANALYSIS OF FACIES PATTERNS

W. C. KRUMBEIN
Northwestern University, Evanston, Illinois

Facies maps based on two sets of contour lines (such as the clastic ratio and sand-shale ratio) may yield patterns with concordant or discordant ratio lines. Selected areas on the maps may be tested for "facies homogeneity" of the individual ratios by ordinary analysis of variance techniques, and multivariate analysis of variance may be used for simultaneous study of both ratios. The methods are applicable to regional or local studies, and examples are given of Pennsylvanian studies from several Midcontinent areas. Application of the technique permits recognition of "facies populations" which in some instances may have economic importance, as for example along basin margins or in areas of sand pinchout along structural flanks.

6. SEDIMENTATION PHENOMENA IN A MOUNTAINOUS SOURCE AREA

F. ALTON WADE
Miami University, Oxford, Ohio

A detailed investigation was made of lateral deposits of sediments along the course of a youthful stream which is eroding a small section of the eastern flank of the northern end of the Wind River Mts. in northwestern Wyoming. Variations in mineral composition, grain size, roundness, sphericity, and surface features were determined, studied, and correlated with each other and with variations in the source rocks in the immediate vicinity of and upstream from each deposit. As the stream is receiving its load in part from primary granite and in part from Paleozoic and Quaternary sediments, the deposits are mixed first- and higher-cycle detritals. Such a source environment is common in the Rocky Mountains, and a great percentage of the clastics presently being deposited in the Great Plains area is obtaining diagnostic characteristics because of modifications which take place during the first few miles of transport.

7. SEDIMENTARY CHARACTERISTICS OF PRODUCING ZONES IN WEST BROCK AREA, CARTER COUNTY, OKLAHOMA

L. L. SLOSS AND E. C. DAPPLES
Northwestern University, Evanston, Illinois

The West Lone Grove, Bayou, and West Brock fields lie along a structural axis trending southeast from the Hewitt anticline to the Criner Hills uplift. Closely spaced drilling and excellent electric log control provide data for detailed analysis of the producing zones and their relation to structural growth. The section concerned is the Deese, including the so-called "Lone Grove series." A cyclical succession, dominated by shale but including numerous sand bodies and minor limestones, is involved. The cycles are identified with

their limestone members as recognized in outcrop.

Sands in the upper part of the section are shown to have a broad "blanket" distribution pattern with production confined to higher parts of closed structures. As the base of the Deese is approached discontinuous sand bodies are present and these have an irregular distribution of productive areas with respect to structure. Maps of numbers of sands, net sand thickness, and average sand thickness show a systematic pattern which is clearly related to the structural trend. Off-structure areas are characterized by high sand thicknesses with large numbers of sands present; higher areas exhibit small or gross amounts of sand confined in fewer individual bodies. In addition, the structurally higher areas are characterized by high rates of change in thickness and number. A combination of rates of subsidence with such environmental factors as waves and currents is invoked to explain the distribution patterns. The characteristics expressed within individual sands may be tested statistically for identification of significant variations.

8. PETROLOGY OF SPRINGER OIL BEARING SANDSTONES

LYNN JACOBSEN

University of Kentucky, Lexington, Kentucky

The oil bearing sandstones of the Springer formation in several large southern Oklahoma oil fields seem to be petrographically distinct from the non-oil bearing ones. In general they are coarser grained and more massive; they do not have a clay matrix, and characteristically they have placer-like concentrations of heavy minerals.

Siderite and pyrite are common in the Springer formation as a whole but are absent from the reservoir sandstones. Calcite, however, occurs with the reservoirs—as clastic grains and to a small extent as cement in the sandstones, and as interbedded thin limestone layers. These associated limestones are either oolitic or debris of benthonic fauna.

The major occurrences of the reservoir type sandstones are on several large anticlinal uplifts, and the sandstones lose their distinctive character down the flanks of the anticlines. Slumped bedding is common on the anticlinal flanks. The character of the reservoir facies and the association of structure with rock type suggests that the loci of the distinctive sedimentation of the oil bearing sandstones was on topographic highs formed by early movements of the uplifts.

It is suggested that the distinctive sandstone is the critical factor in the accumulation of the oil, and hence, that large Springer oil production will be found only on uplifts with a history of movements during sedimentation.

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9. THE ORIGIN OF NATIVE SULFUR IN THE GULF COAST SALT DOMES

J. LAURENCE KULP

Lamont Geological Observatory (Columbia University), Palisades, New York

New light has been shed on the origin of the native sulfur in the Gulf Coast salt domes by measurements of the ratios S^{32}/S^{34} in sulfur compounds and C^{12}/C^{13} in the carbonate cap. In addition quantitative laboratory experiments have been performed in attempts to synthesize sulfur on H_2S from sulfate under the conditions of temperature, pressure, and composition existing in the salt domes. These experiments demonstrate that the inorganic reduction of sulfate is a very improbable hypothesis for the time available. The fractionation observed in the sulfur isotopes between the sulfate and the sulfur in the cap rock is in the same range as that produced by bacteria under similar conditions in the laboratory. The C^{12}/C^{13} ratios in the carbonate cap of sulfur producing domes is in the range of organic carbon, not normal limestone. These new facts suggest that the origin of the sulfur takes place first by the bacterial reduction of sulfate to H_2S with hydrocarbons as an energy source, after which the H_2S is reduced to native sulfur by the reaction with sulfate ion. The correlation of this mechanism of sulfur formation permits prediction of the most likely domes or areas of domes for future exploration.

10. A SIMPLE CORING TUBE FOR SOFT SEDIMENTS*

MARCUS A. HANNA

Gulf Oil Corporation, Houston, Texas

A simple hand operated core barrel with following features:

1. Operated by one or two men depending on length of core cut and depth of water.
2. Relatively light weight.
3. Double tube barrel, inner plastic tube and core easily removed.
4. Ball check valve in top of inner tube eliminates need for core catcher.
5. Has been used in water 15 feet deep.
6. Cutting core causes almost no turbidity in water on top of core resulting in excellent cores for skin studies.
7. Cuts $2\frac{3}{4}$ inch O. D. cores but design can be used for other diameters.

11. MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY IN NORTH-EASTERN UTAH

WALTER SADLICK

Geology Department, University of Iowa, Iowa City, Iowa

Stratigraphic paleontologic investigation of the Mississippian "black shale unit" and the overlying lower lime member of the Pennsylva-

* Presented with permission of Gulf Oil Corporation.

nian Morgan formation in the Uinta Mountains has yielded evidence concerning the position of the Mississippian-Pennsylvanian boundary in Utah. The black shale unit contains *Cravenoceras nevadense*, Miller and Furnish, *Neospirifer* aff. *N. cameratus* (Morton), *Dictyoclostus* cf. *D. coloradoensis* (Girty), ostracodes, and at the base a pinnule similar to *Cardiopteris hirta* White. This assemblage is similar to that of the Fayetteville formation of Arkansas. *Rhipidomella nevadensis* (Meek) overlies this fauna in the upper beds of the Manning Canyon shale of the Great Basin but it has not been found in the black shale unit. Present evidence suggests a correlation of the black shale unit with the Manning Canyon black shale of the Great Basin, and the apparent absence of the *Rhipidomella nevadensis* zone suggests a disconformity between the Manning Canyon shale of the Uinta Mountains and the overlying lime member of the Morgan formation. The uppermost 1,100 feet of the Brazer formation in the Dry Lake section, 15 miles southwest of Logan, is lithologically similar to the type Manning Canyon shale and contains near the top the *Rhipidomella nevadensis* zone, suggesting a direct correlation.

The lower lime member of the Morgan formation has been traced to beds in the eastern Uintas tentatively assigned to the Belden formation by Thompson on the basis of fusulinids. The fossils, which are partly replaced by jasper, include *Wellerella osagensis* (Swallow), spiriferoids of the group of *S. rockymountanus-opimus-matheri-occidentalis*, *Cleiothyridina orbicularis* (McChesney), and *Composita ozarkana* Mather, in addition to ostracodes and forams that indicate a Morrowan age. The lower lime member has been traced to the type section of the Morgan formation and is found to underlie it; furthermore, it has been included as a part of the Brazer formation by previous geologists. Since this lower lime member is a distinct lithologic unit, a new name is being proposed in a forthcoming publication. The lower 1,200 feet of the Oquirrh formation of the Great Basin contains a fauna similar to that found in the lower lime member of the Morgan formation suggesting that these stratigraphic units are partly equivalent in age.

Wednesday, April 14, 9:00 A.M.
Opera House, Kiel Auditorium

JOINT TECHNICAL SESSION
PAPERS OF GENERAL INTEREST

Wednesday, April 14, 1:30 P.M.
Assembly Hall No. 2, Kiel Auditorium

SYMPOSIUM ON FAUNAL FACIES AND THEIR LITHOLOGIC ASSOCIATIONS

Presiding: E. C. DAPPLES, Northwestern University, Evanston, Illinois and HEINZ LOWENSTAM, California Institute of Technology, Pasadena, California

1. SOME MODERN FAUNAL AND LITHOLOGIC ASSOCIATIONS

FRED B. PHLEGER
Scripps Institution of Oceanography,
La Jolla, California

This discussion is essentially confined to biofacies existing in areas of non-calcareous, detrital sediments. Foraminifera are emphasized because their ecology is best known, and any such group of variable organisms should illustrate principles.

Known depth distributions of benthonic Foraminifera show widespread boundaries at 100 m., 200 m., 500 m., and 2000 m., and larger invertebrates are believed to have similar bathymetric patterns although less is known about them. Nearshore distributions of both Foraminifera and macroorganisms in the Gulf of Mexico show a basic pattern of lagoon and open-ocean biofacies, and these can be further subdivided.

Depth biofacies of Foraminifera show only a very general relationship to sediment type where continental shelf, continental slope, and deep-sea sediments can be differentiated. Many nearshore facies of Foraminifera appear to be developed regardless of sediment type. Exceptions are beaches, coral reefs, marine marshes, and areas of rocky or stony bottom. Some facies of macroorganisms show a better relationship to sediment.

Correlation of faunas with sediment type has an ecologic significance in attached forms, coral reef associations, and burrowing types; it appears that mud-sand areas can support a very large population. In the southern Gulf of Maine an excellent correlation between biofacies and lithofacies is shown to be a coincidence. Where such correlation exists it is believed generally due to oceanographic factors which affect both sediments and organisms.

Mixing of foreign dead populations with an endemic living population may occur on a beach, in vertically displaced sediments such as from turbidity flows, and in areas of sediment deposited

in a previous environment. Submarine erosion of sediments containing fossil faunas also may be significant. Foraminifera populations do not appear to be transported significant distances in most environments except where masses of sediment also are transported. Problems in dealing with a population of planktonic organisms are discussed. Tentative principles of distribution of Foraminifera are enumerated; it is believed that these distribution principles apply to other groups of organisms which are potential fossils.

2. RELATIONSHIPS OF INVERTEBRATE ORGANISMS IN PENNSYLVANIAN STRATA

L. M. Cline

University of Wisconsin, Madison, Wisconsin

This paper presents some of the results of some paleoecological studies of Pennsylvania faunas of the Mid-Continent region. The project has been a group effort and several men who are now at or who have been at the University of Wisconsin have contributed significantly to the study; these include B. H. Burma, George A. Risley, Edward Heuer, Donald Lokke, Frank Brown, and David DeVries.

The cyclically arranged Pennsylvanian strata of the platform facies of the northern Mid-Continent are characterized by the rapid alternation of marine and non-marine beds, a large number of thin but laterally persistent rock units, and a diversity of rock types. This combination of lithologic features provides the type of control needed for paleoecologic studies. The simple cyclothem so characteristic of the Desmoinesian includes strata that ranged from fresh-water to marine environments and it embraces all of the common sedimentary rock types. The vertical interval from the coal upward to the marine limestone represents a gradual increase in depth and salinity of water that is reflected in gradual changes in faunas. Vertical changes are to some extent duplicated in individual members by lateral changes of a more regional nature. Virgilian strata in the Sacramento Range of New Mexico have a cyclic arrangement. The limestone members of some of the cyclothems show an upward gradation from thin-bedded fusulinid-bearing strata having a molluscoidean fauna into a massive algal biostrome cap, the gradation being interpreted as the result of gradually shoaling conditions. The vertical variation is repeated laterally as individual limestones are traced toward the ancient Pedernal landmass; the fusulinid-bearing strata grade shoreward into algal limestones which in turn eventually break down into a mass of calcareous nodules embedded in red shale.

3. RELATIONSHIP BETWEEN FAUNA AND LITHOLOGY IN THE MOENKOPI FORMATION*

Edwin D. McKee

U. S. Geological Survey, Denver, Colorado

A close relationship exists between faunas and rock types in the Moenkopi formation of Triassic age in northern Arizona and southern Utah. This formation consists of marine sediments to the west, and continental sediments to the east and intermediate intertonguing.

Marine deposits consist of (1) limestone and (2) gray calcareous siltstone, that alternate to form seven or more cycles. The limestone, apparently developed in clear shallow waters, contains an abundance of crinoids, terebratulid brachiopods, a *Pugnoides*-like brachiopod, and a few types of large pelecypods, notably *Aviculopecten*. Siltstone, formed as the shallow waters silted up intermittently, contains many species of small gastropods, and the crustacean *Halicyne*.

The continental deposits consist principally of (1) red shaly siltstone of mud-flat origin, (2) red structureless mudstone, formed in bodies of quiet water, and (3) thick-bedded sandstone deposited in stream channels. Abundant reptilian footprints and some reptile bones constitute the faunal record of the mud flats; no fossils are found in the red mudstone; skulls, and other bones of large amphibians, and a few amphibian tracks are present in the stream deposits.

Other environments of the Moenkopi include lagoons, indicated by deposits of gypsum, and fresh- or brackish-water ponds, represented by pelecypod- or fish-bearing limestones. Intraformational conglomerates, some containing mud and clay pellets—others limestone pebbles—are numerous but local. Many of them contain accumulations of water-worn bones of vertebrate animals.

4. A QUANTITATIVE LITHOFACIES AND BIOFACIES STUDY OF THE FLORENA SHALE (PERMIAN) OF KANSAS

John Imbrie

Columbia University, New York, New York

The purpose of this study is to test the practicality and scientific potential of an analytical technique designed to produce quantitative data on biofacies and lithofacies changes. The unit selected for analysis is the Florena shale member of the Beattie limestone (Wolfcampian), a fossiliferous unit traceable across Kansas from Nebraska to Oklahoma.

Seventeen complete sections of the Florena, spaced as evenly as possible over the belt of outcrop, were studied. In addition to field procedure usual in biostratigraphic work, trench samples were taken, each sample totaling eleven pounds and representing no more than one foot of section. One pound of each sample was saved for lithologic analysis. The remaining ten pounds were disaggregated and sieved, selected fractions being separated into fossil and non-fossil portions. The fossil portion, comprising whole specimens and fragments, was separated into taxonomic groups and each group weighed.

These weights provide an accurate estimate of the abundance of the taxonomic category in the sample. Although such a measure is of little value by itself, systematic changes in fossil abundances

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of samples taken at different stratigraphic and geographic positions may be highly significant.

It is obvious that a complex of factors, random and non-random, primary and secondary, will affect fossil abundance. In the Florena shale, however, the abundance of many groups of fossils shows systematic geographic and stratigraphic variations; and it is therefore probable that (in this case) non-random changes are being measured. Petrographic and chemical analyses of the same samples also show systematic lithologic changes. Paleontologic and lithologic data can thus be conveniently compared and facies relationships precisely and objectively formulated. The documentation of these relationships, in turn provides a sound basis for hypotheses of primary (ecologic or evolutionary) and secondary (diagenetic) control.

5. SAMPLE-POPULATION CONCEPTS IN FAUNAL-LITHOLOGIC FACIES STUDIES

ROBERT L. MILLER AND EVERETT C. OLSON
University of Chicago, Chicago, Illinois

Whenever collections are made in the field it should be recognized that a sampling procedure is involved. That is, the geologist wishes to draw inferences about a much larger aggregate on the basis of the sample he has drawn. In general, inferences may be drawn from a sample with or without the aid of statistical methods. In either case a fundamental consideration is involved. It is to determine the nature of the population or universe from which the sample is drawn.

In this talk the authors focus their attention on the relations between studies of ancient and modern environments. The discussion is in terms of sample vs. population in order to facilitate a theoretical examination of some applications of statistics to various aspects of environmental studies.

Particular attention is paid to the following:

1. The use of modern studies to construct models for use in studies of ancient environments.
2. The concept of key measures and key patterns involving both fauna and lithology.
3. A quantitative model, as an alternative approach to the facies concept.

ANNUAL BUSINESS MEETING

Presiding: HAROLD N. FISK

Thursday, April 15, 9:00 A.M.
Assembly Hall No. 2, Kiel Auditorium

SYMPOSIUM ON REGIONAL ASPECTS OF CARBONATE DEPOSITION

Presiding: DAN FERAY, Magnolia Petroleum Company, Dallas, Texas, and FRANK E. LOZO, JR., Shell Oil Company, Houston, Texas

PART I—PRESENTATION OF PAPERS

1. THE DISTRIBUTION OF MARINE CARBONATE SEDIMENTS

JOHN RODGERS
Yale University, New Haven, Connecticut

Modern marine carbonate sediments may be roughly grouped into three main classes: Deep-water oozes, organic ("coral") reefs and associated deposits, and continental shelf lime-sands and lime-muds; the last two overlap somewhat.

Carbonate ooze covers vast areas on the bottoms of the three great oceans, especially in low latitudes and where the water is less than 3 miles deep. Tests of pelagic foraminifers are the principal component of at least the purer oozes, though pteropod shells and coccoliths are locally important. Clayey carbonate ooze occurs in somewhat deeper water and also toward coasts where there is much terrigenous sediment; it is common in the deeper basins of the world's mediterraneans. Such ooze probably did not form before the Cretaceous; the accessible geologic record apparently contains nothing like the ooze of the open ocean but may contain deposits like those in the modern mediterraneans.

Organic reefs are practically confined to low latitudes; atolls dot the open oceans but the largest reef areas are on continental margins, as in the East and West Indies. Here the reef deposits are associated with wide areas of shelf carbonate deposits, chiefly fragmental-organic, but with chemical deposits locally. Deposits of this type, with local areas of reefs, have been common since the Middle Ordovician on shelves and in epeiric seas; before that chemical precipitation probably played a relatively more important part. In general shallow-water carbonate deposits seem to have been more common during the late Precambrian, Paleozoic, and Mesozoic than during the Cenozoic or today.

2. CALCIUM CARBONATE DEPOSITS OF THE GREAT BAHAMA BANK, BRITISH WEST INDIES

NORMAN D. NEWELL AND J. KEITH RIGBY
American Museum of Natural History and Columbia University, New York, New York

(To be presented by WALTER H. BUCHER, Columbia University, New York, New York)

Southeast of Florida the continental shelf forms an enormous limestone plain of which nearly 60,000 square miles has a mean relief of about 30 or 40 feet. This is the Bahama Plateau, much of which is barely awash at low tide. Conditions of sedimentation here must closely resemble those responsible for many of the limestone deposits so characteristic of Paleozoic and Mesozoic shelf seas. Nearly three miles of pure carbonate deposits were laid down in the Bahamas during the Cenozoic era, indicating very high average rates of deposition limited probably only by the rate of subsidence.

The Bahamas are bathed by the warm Antillean Current on the northeast and by the Florida Current on the west. Both streams continually bring great quantities of calcium carbonate to the shallow banks. The main bank and separate outliers are all rimmed by coral reefs and low islands thrown up by waves and wind; the highest and most extensive areas of elevated rim lie on the windward, eastern side of each bank. Comparatively fine sediments are trapped and deposited in the shallow central basins of the banks. Dominantly organic sediments—coral reefs and reef detritus—are being produced around the rim of each bank, whereas chemical precipitates in the form of calcareous ooze and oolite sand are the principal sediments being formed within the bank areas.

The plateau is bounded by very steep slopes that extend to great depths, comparable with those of oceanic coral atolls, and, as with the latter, suggestive of nearly vertical reef growth during subsidence, modified, doubtless, by wave action during low sea levels.

3. EARLY DIAGENESIS AND LITHIFICATION OF CARBONATE SEDIMENTS IN SOUTH FLORIDA

ROBERT N. GINSBURG
University of Miami-Marine Laboratory, Coral Gables, Florida

Diagenesis and lithification include processes which convert sediment into rock. They are of special importance to the study of limestones because of the ease with which they modify the texture, structure, and composition of carbonate sediments. The intense physical, chemical, and biological processes which operate during deposition and within the first few feet of burial comprise Early Diagenesis. Subsequent processes are of longer duration and less intensity. Grain size and related properties exercise some control on the rate and extent of diagenesis in both phases.

Physico-chemical precipitation of calcium carbonate in the shallow tropical seas occurs under extreme conditions of temperature, salinity, and nucleation. It may also take place within submarine sediments, but apparently not as a lithifying cement. Petrographic comparison of lithification of the late Pleistocene Miami Oolite with that of the Mississippian Fredonia Oolite suggests that cementation in both cases was accomplished only after removal from the marine environment. Unlithified carbonate sediments found well below the surface on some Pacific atolls support this view.

4. MISSISSIPPIAN CARBONATE DEPOSITS OF THE OZARK REGION

RAYMOND C. MOORE
University of Kansas, Lawrence, Kansas

Rocks of the Mississippian System, which originally covered all of the Ozark region in Missouri and adjacent states, consist mainly of carbonate deposits. Study of the nearly continuous outcrops of Mississippian formations now found on the flanks of the Ozark dome leads to recognition of several distinct types of carbonate rocks and permits determination of their regional stratigraphic relations. The widespread occurrence of siliceous sediment in the form of chert nodules and beds is an outstanding peculiarity of some formations, whereas chert is virtually unknown in others. This dissimilarity and the observation that chert associated with various stratigraphically distinguishable parts of the Mississippian deposits in this region are features which cannot be ignored in research on the nature of sedimentation that produced the carbonate rocks. Most of the differences are primary.

Data and conclusions given in the present paper are based largely on field work undertaken in 1953 for the purpose of lithologic sampling but they embrace also extensive previous acquaintance with the rocks discussed.

PART II—PANEL DISCUSSION

Thursday, April 15, 1:45 P.M.
Assembly Hall No. 2, Kiel Auditorium

GENERAL PALEONTOLOGY AND STRATIGRAPHY

Presiding: F. M. SWAIN, University of Minnesota, Minneapolis, Minnesota, and ALLEN F. AGNEW, U. S. Geological Survey, Platteville, Wisconsin

1. BRAZILIAN DEVONIAN CARPOIDS

KENNETH E. CASTER
University of Cincinnati, Cincinnati, Ohio

Two new genera of carpoid echinoderms from the Ponta Grossa (Devonian) shale of Parana, Brazil, are described. These are the first carpoid echinoderms to be reported from South America, and the second occurrence in the Southern Hemisphere, three specimens from the Union of South Africa being the only previous discoveries, and in beds of the same age as the Ponta Grossa shale.

The Brazilian forms are of two distinct lineages one of the placocystoid general organization, the other recalling somewhat in its exceptional asymmetry the lagynocystids of Europe. The Brazilian fossils are quite distinct from the placocystoid forms from South Africa, a revision of which is also undertaken in the present study.

These new organisms serve to epitomize the paleogeographic isolation of Afro-Brazilian faunas in Lower Devonian times, and the highly autochthonous aspect of the fauna.

2. LITHOLOGIC AND FAUNAL CHARACTERISTICS OF LOWER CRETACEOUS AND PRE-CRETACEOUS (?) LIMESTONES OF SOUTH PENINSULAR FLORIDA*

P. L. AND E. R. APPLIN
U. S. Geological Survey, Jackson, Mississippi

A thickness of more than 5,000 feet of carbonate rocks and evaporites of early Cretaceous and Jurassic? age constitutes the larger part of the subsurface stratigraphic section near the south end of the Florida peninsula. Relations between the Lower Cretaceous units in Florida and units of equivalent age in Mexico and Texas are discussed and correlations suggested. A possible Jurassic age is suggested for the limestone and dolomite penetrated in the basal part of two wells in south Florida. Twenty-four photomicrographs of thin sections of the carbonate rocks demonstrate characteristic lithologic and microfaunal features of the Lower Cretaceous and Jurassic? units, and four plates show diagnostic microfossils.

3. RECENT OSTRACOD BIOFACIES IN EAST MISSISSIPPI DELTA AREA†

DORIS MALKIN CURTIS
La Jolla, California

Ostracoda were studied from Recent samples collected in the East Mississippi Delta Area as part of A. P. I. Project 51 (Study of Recent Nearshore Sediments in the Gulf of Mexico). Frequency distribution of the species in this area indicates that several distinct environments can be recognized by their characteristic ostracod assemblages. The three principal biofacies in the area are (1) marsh facies, (2) Breton Sound facies, and (3) open Gulf facies. A zone of mixing connects the open Gulf and Breton Sound facies.

The marsh biofacies is characterized by extremely rare individuals and species, generally fresh to brackish water types.

The Breton Sound biofacies may be divided into:

(a) *Inner Breton Sound subfacies*, characterized by the presence of numerous individuals belonging to relatively few ostracod species, including *Trachyleberis* cf. *T. exanthemata*, *Hemicythere* sp., *Perissocytheridea* spp., *Cytherura* spp., *Microcythere* sp., *Candona* sp.

(b) *Breton Sound subfacies*, characterized by the presence of numerous individuals in relatively few ostracod species, including *Perissocytheridea* spp., *Cytherura* spp., *Loxoconcha* spp., *Leptocythere* sp., *Microcythere* sp., "*Cytheridea*" sp., *Cytherideis* spp.

Most species of the Breton Sound facies are found in the mixing zone.

The open Gulf biofacies may be divided into:

(a) *Nearshore subfacies* (in area of pro-delta clays and silts), characterized by relatively rare individuals and few species, including *Favella* cf. *F. rugipunctata*, *Cythereis echinata*, *Pellucistoma* sp., *Cytherideis* spp., *Cytheretta* sp. *Microcythere* sp. The species of this subfacies are found in the mixing zone.

(b) *Offshore subfacies* (in area of offshore clays), characterized by abundant individuals of many species, including *Trachyleberis* sp., *Favella* cf. *F. rugipunctata*, *Cythereis echinata*, *C.* cf. *C. margaretifera*, *Pellucistoma* sp., *Cytherideis* sp., *Cytheretta* sp., *Pterygocythereis* sp., *Hemicythere* sp., *Krithe* aff. *bartonensis*, (?) *Macrocytherina* sp., *Cytheropteron* sp., *Brachycythere* sp., *Cytherella* sp., *Cytherelloidea* sp., etc.

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† This investigation was supported by a grant from the American Petroleum Institute, Project 51.

4. POST-GLACIAL STRATIGRAPHY ALONG THE CENTRAL TEXAS COAST*

F. P. SHEPARD AND D. G. MOORE
Scripps Institution of Oceanography, La Jolla, California

Twenty holes with an average depth of 55 feet were drilled into the barrier islands, bay floors, and into a bay head delta in the Rockport-Aransas Pass area of the Texas coast. The extensive criteria developed previously for recognition of depositional environments in this area were used to interpret the drill samples. These borings, which were mostly a combination of three feet washing and two feet coring, indicate a general uniformity of conditions during the several thousand years which are believed to have followed the last major rise in sea level at the end of the Pleistocene. In Lower San Antonio Bay a section of 80 feet was penetrated before reaching the base of bay deposits similar to those of lower bays of the present day; whereas under the Guadalupe Delta a section of 50 feet was crossed before getting below deposits characteristic of upper or middle bay conditions. Under the gulf beach of Saint Joseph Island the drill penetrated 65 feet before getting out of formations characteristic of various parts of the present barrier islands including beaches, dunes, and inlets. In middle San Antonio Bay, where oyster reefs form numerous shoals at the present time, a thickness up to 50 feet of oyster reef material was traversed in getting below the bay deposits.

There are many problems arising from the study of the cores which are proving difficult to explain without more extensive drilling. However, the indications from the available material are that either the area has been sinking with deposition keeping pace since the return of the sea at the end of the glacial period, supposedly some 6,000 years ago, or that the deposits were formed at least in parts as the sea level rose. Deposition of the entire section during rise in sea level seems unlikely because of the long interval since the return of the sea and because bay deposition is now occurring at rates in excess of one foot per century. In any case it seems likely that barrier island sands can develop considerable thicknesses between the silts and clays of the bays on one side and of the open continental shelf deposits on the other resulting, after burial, in the production of stratigraphic traps for future petroleum.

5. NON-MARINE FRONTIER MICROFAUNA, COALVILLE AREA, UTAH

DANIEL J. JONES
University of Utah, Salt Lake City, Utah

Foraminifera and marine Ostracoda have been previously described in the Coalville Area of northeastern Utah. However, recent work in the area has demonstrated the existence of 10 feet of fossiliferous non-marine strata in the lower portion of the Frontier a few miles southwest of good exposures of the marine section. Several species of Charophyta and non-marine Ostracoda are described and illustrated. It is inferred from the microfossil evidence that the non-marine facies represents flowing of continental sediments into lagoonal or marginal areas of the Frontier sea from nearby positive elements of the Wasatch and Uinta uplifts.

* This investigation was supported by a grant from the American Petroleum Institute, Project 51.

6. A CRETACEOUS VERTEBRATE FAUNA OF MINNESOTA AND SOUTH DAKOTA

ROBERT E. SLOAN
University of Minnesota, Minneapolis, Minnesota

A thin arkosic conglomerate rests directly on top of an Archean gneissic granite in a series of outcrops and quarries along the southern edge of the Minnesota River valley in Grant County, South Dakota and Lac qui Parle County, Minnesota. It is probably to be correlated with the Benton group, possibly with the Graneros formation. Elements of the fauna present include a species of *Ichthyodectes;* Toxochelid and Protostegid turtles, a Ptychodont and several sharks. In addition carbonized wood from a gymnosperm is present. The conglomerate is apparently part of the overlapping sequence of Upper Cretaceous sediments and represents a near shore environment.

7. SOME FORAMINIFERA, RADIOLARIA AND OSTRACODA FROM THE CRETACEOUS OF MINNESOTA

EDWARD J. BOLIN
State Geological Survey, Vermillion, South Dakota

Two microfaunas consisting of twenty-one species of Foraminifera, one of Ostracoda, and three of Radiolaria are described and illustrated from the Cretaceous of Minnesota.

Outcrop samples from Lyon and Redwood counties yielded a fauna including eleven species of calcareous Foraminifera, one ostracode of the genus *Cythereis*, and three species of nasselariad radiolaria. The eleven species of Foraminifera, Representing the genera *Gumbelina*, *Loxostoma*, *Globigerina*, *Globigerinella*, *Gyroidina*, *Neobulimina*, *Planulina*, and *Anomalina*, suggest that these sediments are the age equivalent of the Niobrara formation.

A foraminiferal fauna consisting of one calcareous and nine arenaceous species was encountered in the Coleraine formation from drill holes between the Mesabi and Cuyuna iron ranges, in Aitkin and Crow Wing counties. The calcareous species, *Globigerina washitensis* Carsey, was represented only by two glauconitized specimens. The nine arenaceous species, representing *Ammobaculites*, *Ammobaculoides*, *Haplophragmoides*, and *Trochammina*, are described as new. The nature of the fauna suggests a near shore, cold, and probably brackish water environment.

8. THE ISOLATION AND CULTIVATION OF MICRO-ORGANISMS FROM DEEP WELL BORINGS IN THE WILLISTON BASIN

JAMES M. WILLIAMS, WILLARD D. PYE, AND CASPER I. NELSON

Departments of Geology and Bacteriology, North Dakota Agricultural College, Fargo, North Dakota

As part of a continuing research program dealing with various geological problems of the Williston Basin, a project was undertaken to determine the physical properties of the brines produced from wells drilled within the Basin.

Samples of fluids were secured from two wells in the Beaver Lodge, North Dakota, field and one sample each from the Richey and Pine Unit, Montana, fields; and one from a wildcat dry hole in Bottineau County, North Dakota. Fluids were from Mississippian formations at depths of 7,000–8,000 feet.

The organisms examined were anaerobic. Aerobic bacteria, if present in the fluid, were not studied as they could have resulted from contamination. Tests were made for contamination and media were used which would not support most of the contaminants. The anaerobic bacteria were best isolated from the brines rather than the oil fractions of the fluid.

An environment of pure nitrogen proved to be most suitable for the initial isolations, and a temperature of 45°C. was the most satisfactory. The most successful growing medium consisted of 2% yeast extract (Difco), 0.2% NH_4Cl, 0.2% $NaNO_3$, 0.2% Na_2SO_3 and water. After the medium was sterilized, a 1% solution of ferric sulphate was added aseptically. The final pH was 7.0. Reduced methylene blue was used as an indicator of anaerobiosis.

After preliminary isolations were made, it was found that fluid Thioglycollate Medium (BBL) could be used in an anaerobic environment. After considerable cultivation, the optimum temperature for incubation could be reduced to 30° C.

Five different types of organisms were isolated. Of the organisms isolated one proved to be *Desulfovibrio* sp. (probably *D. desulfuricaus*), three appear to belong to the Clostridium group and one has yet to be idenified.

Desulfovibrio sp. rapidly reduced a 1% solution of ferric sulphate to ferrous sulfide. The organisms rapidly died out when the cultures were exposed to atmospheric oxygen. All of the isolated organisms attacked various carbohydrates to form various organic acids and in some instances gases. All but the form *Desulfovibrio* sp. will eventually reduce the carbohydrate acid to neutral compounds. These same bacteria will attack the protein casein, with the production of an acid coagulation of the proteins followed by a digestion of the coagulated substances. All but one of the organisms, exclusive of *Desulfovibrio* sp., exhibit proteolytic activity by liquefying gelatin. These reactions are accompanied by the release of carbon dioxide and hydrogen sulfide. Some of these isolates are capable of nitrate reduction, which could account for the presence of nitrites in the brine samples.

The geological significance is that the isolated bacteria not only are capable of attacking and reducing carbohydrate and protein material to possible precursors of petroleum but in so doing release various gases characteristic of oil fields and the organic and inorganic acids which they produce are capable of attacking carbonates thus developing porosity and liberating absorbed oil.

9. DISTRIBUTION OF MARINE UPPER JURASSIC OSTRACODES, WESTERN INTERIOR UNITED STATES

JAMES A. PETERSON

Shell Oil Company, Salt Lake City, Utah

Micropaleontologic studies indicate the presence of two distinct ostracode biofacies in the Rierdon formation and equivalent rocks in Montana and Wyoming, whereas only a single ostracode zone is present in the overlying Swift formation and equivalent rocks of the same area. Distribution of the two Rierdon assemblages was apparently governed by the presence of an east-west arch (the "Sheridan Arch") across north central Wyoming and southeastern Montana during at least the early part of Upper Jurassic time. The zone found in the Swift formation contains an ostracode assemblage closely related to that present southeast of the Sheridan Arch during Rierdon deposition, but the forms present in the Rierdon northwest of the arch have not been found in the Swift and equivalent rocks. These facts, in conjunction with stratigraphic data, imply several conclusions regarding Upper Jurassic paleogeography and may provide additional clues regarding the changing sedimentary and paleogeographic picture during the transition period between the fading out of the Paleozoic Cordilleran Geosyncline and the beginning of the trough system which dominated Western Interior sedimentation during the middle and late Mesozoic era.

10. PALEOZOIC FOSSILS IN CRETACEOUS CONGLOMERATES FROM COLORADO

JOHN CHRONIC

University of Colorado, Boulder, Colorado

Well preserved, silicified, invertebrate fossils of late Paleozoic age have been found in basal Cretaceous conglomerates, along the Front Range and in North Park, Colorado. Fusulinids, sponge spicules, corals, brachiopods, bryozoans, mollusks, and echinoderms have been recognized. Specimens occur in rounded chert and silicified sandstone pebbles up to approximately two inches in diameter.

Apparent uniformity of fauna in the pebbles over a considerable area, and their abundance in most sections in the area, indicate an extensive supply of Paleozoic sediments at the beginning of Cretaceous deposition.

Three sources for the pebbles seem possible:

1. They may have been weathered from Mor-

rison or pre-Morrison conglomerates during early Cretaceous time, and redeposited without appreciable transportation.

2. They may have been eroded from some original source in the region, through a 'hole' or 'holes' in the Morrison formation, and distributed by fluvial or marine processes which deposited the basal part of the Dakota group.

3. They may have been eroded from some original source outside the area covered by the Morrison formation, and carried into their present site by fluvial and/or marine agencies.

Bryozoans dominate in the pebbles; mollusks are rare and poorly preserved. Ecologically, this relationship suggests that the original fossil-bearing sediments were deposited in relatively quiet, clear, marine waters at a considerable distance from shore.

11. LATE MISSISSIPPIAN-EARLY PENNSYLVANIAN OF SOUTHERN MIDCONTINENT

MAXIM K. ELIAS

University of Nebraska, Lincoln, Nebraska

Intensive field investigations in south-central Oklahoma conducted in the last decade by several geologists resulted in rediscovery of old and discovery of many new fossil localities in the late Mississippian and early Pennsylvanian formations. The study of the fossils collected by them and by me, together with subsequent additional field work, resulted in considerable modification of our understanding of the local stratigraphy and correlations, particularly of the Caney, Springer and Morrow. Conodonts, goniatites, and also some other mollusks, ostracodes and brachiopods have restricted stratigraphic range, and the established succession of the goniatites allows close correlation with the corresponding zones of Britain and western Europe. The zones involved are the Namurian (E, H, and R), and the lower Westphalian (G).

12. LITHOLOGIC FEATURES OF CORES OF JURASSIC LIMESTONE FROM A DEEP WELL IN SOUTH MISSISSIPPI*

P. L. APPLIN AND E. R. APPLIN

U. S. Geological Survey, Jackson, Mississippi

Fourteen photomicrographs of thin sections show distinctive lithologic features of a series of cores of limestone of Jurassic age from depths of about 19,000 to 20,000 feet in the George Vasen Fee well 1, Stone County, Miss.

13. A PALEOECOLOGICAL STUDY OF THE VIESCA MEMBER OF THE WECHES FORMATION, SMITHVILLE, TEXAS

(Read by title only)

NEVILLE M. CURTIS, JR.

Department of Geology, Marietta College, Marietta, Ohio

Interpretation of the environment in which the Viesca member of the Weches formation at Smithville, Texas was deposited is based on three lines of evidence: (1) regional tectonic framework during Weches time; (2) sedimentary characteristics of the Weches formation at Smithville and other localities; and (3) variations in percentage of foraminiferal species throughout the Viesca section of the Weches at Smithville.

The source area for the Viesca sediments is considered to have been the Llano uplift area, with the Colorado River transporting the majority of the sediments. The age of the source rocks is considered to be no older than Edwards and no younger than Viesca. The Llano uplift area is thought to have been stable to mildly epeirogenic during Viesca time.

The rate of deposition (slow), chemical stability of water, degree of tectonic activity (stable) in the depositional area, are based on the glauconite, which is found in great abundance throughout the Viesca member.

Interpretations based on the relationship (variations in frequency percentage) between *Siphonina claibornensis* and *Quinqueloculina claiborniana* show that during Viesca deposition there was oscillation of sea level in the Smithville area. Water depths ranged from 3 feet to approximately 100 meters. The section is divided into four depth zones: 0–40 meters, 30–50 meters, 50–80 meters, and 70–100 meters.

The salinity (16.5–35%) or chlorinity (10.0–19.0%) interpretations are based on the presence of the oyster "bank" in the Viesca member. The temperature (14°C.), pH of water (approximately 8.2), and turbidity of water (low) are also interpreted from the oyster bank.

Environmental analysis by means of Foraminifera is supported and supplemented by other lines of evidence. It is possible to reconstruct environment from a single short (10 foot) section, but regional studies are necessary for a complete picture.

ANNUAL BUSINESS MEETING

The annual business session of the Society was called to order at 4:30 P.M., Wednesday, April 14, by Harold N. Fisk, president, who introduced the officers for the new year as follows: President, Hans E. Thalmann; Vice-President, F. J. Pettijohn; Secretary-Treasurer, Samuel P. Ellison, Jr. It was announced that Editor Jack Hough had accepted a two-year assignment in India and Ralph E. Grim, the new acting editor of the *Journal of Sedimentary Petrology*, was introduced.

It was moved by Hans Thalmann, seconded and approved that the minutes of the 1953 meeting be approved as published in the *Journal of Paleontology*, vol. 27, no. 4 (July, 1953).

The following reports were given.

1. *Report of the Editor of the Journal of*

* Published with permission of the Director, U. S. Geological Survey.

Paleontology (*Grover E. Murray*).—Volume 27 of the *Journal of Paleontology*, issued in conjunction with the Paleontological Society in 1953, contains 912 pages and 91 collotype plates. Published in it are 54 papers; 1 bibliography and index of Foraminifera; 19 paleontological notes; 14 nomenclatural notes; 2 memorials; and miscellaneous notes, reviews, and Society records.

Volume 27 represents a decrease of 104 pages and 44 collotype plates over volume 26.

The March, July, and November numbers were prepared by your editor on behalf of the S.E.P.M. These numbers consist of 439 pages and 44 collotype plates, a decrease of 39 pages and 6 collotype plates over corresponding issues of the previous volume. Publication of manuscripts has been continued at a rate which guarantees publication in about nine months.

Financially, the savings resulting from the decrease in published pages and plates was more than offset by a 15 per cent increase in engraving charges. Although small savings can be effected occasionally, appreciable reductions in publication costs must come about as a result of (1) reductions in the amount of published pages and collotype plates, or (2) a reduction in the cost of printing and engraving. Increased advertising still appears to offer one of the best sources of untouched income. As in 1952, Louisiana State University provided support for the *Journal* by defraying part of the cost of an editorial assistant and all the costs of miscellaneous supplies and expenses involved in editing.

The March, July, and November issues contributions which may be classified as:

	Paleozoic	*Mesozoic*	*Cenozoic*	*Miscellaneous*	*Total*
Radiolaria		1	1		(1)*
Foraminifera	3	1	6	1	11
Crinoids	2			1	3
Brachiopods	1				1
Mollusca			1		1
Cephalopods	2				2
Pelecypods			2		2
Trilobites	1				1
Ostracoda	1		1		2
Miscellaneous		1	1		2
	10	3	12	2	26

* Paper deals with both Mesozoic and Cenozoic forms.

Five of these papers are concerned with fossils outside of North America; four are on phylogeny and taxonomy; one is a statistical study; four concern ecology and paleoecology; twelve primarily describe fossil or living forms; and one each is concerned with facies and fauna, biostratigraphy, and oscillation charts. In addition, there are: one bibliography and index of Foraminifera, twelve paleontological notes, four nomenclatural notes, two notes on techniques and procedures, one report on reviews, two memorials, and miscellaneous errata, notices, news and events, and society records and activities.

Policy-wise your editor has continued: (1) to give priority to those papers which appear most timely and of greatest economic pertinency; (2) to encourage authors to include geographic and stratigraphic data related to their problem; and (3) to encourage authors, where possible, to use line drawings for illustrating morphological or stratigraphical features discussed in their articles. A section on current news and events was instituted and contributions are requested.

Considerable time was devoted during the year to: (1) discussions with the Paleontological Society concerning costs and related items, and (2) publication of an index for the first 25 volumes of the *Journal*. Your editor also participated in the Paleontological Society council meetings in Toronto in November, 1953, as the official representative of the S.E.P.M.

With the death of Co-editor Wilbert in March, 1953, your officers approved the appointment of Associate Editors W. C. Bell, J. W. Durham, I. R. Hessland, S. A. Levinson, A. K. Miller, M. B. Stephenson, Erik N. Kjellesvig-Waering, and Teiichi Kobayashi.

2. *Report of the Editor of the Journal of Sedimentary Petrology* (*Jack L. Hough—Presented by Ralph Grim*).—The *Journal of Sedimentary Petrology* was published in 1954 as volume 23, numbers 1 through 4. Numbers 1 and 3 contain 64 pages, number 2 contains 79 pages, and number 4 contains 100 pages, a total of 51 pages over the authorized maximum of 256. Fourteen hundred copies of each issue were printed. The contents of the volume include 29 technical

articles, 2 notes, 9 reviews, 5 pages of news and announcements, abstracts of papers given at the 1953 S.E.P.M. meeting in Houston, and an index. One one-half page advertisement of Society publications was run, and three full page paid advertisements were run.

The distribution of articles and notes according to national origin was as follows: United States, 28; New Zealand, 1; Canada, 1; and Gold Coast, West Africa, 1.

The size of the *Journal* has been increased tentatively in an attempt to adjust to a growing backlog of manuscripts which now amounts to a 12-months' supply.

The cost of production exceeded the income from membership dues assigned to the *Journal* and from subscriptions by $425.74. As in the past four years, the University of Illinois has provided a half-time editorial assistant.

Special Publication No. 2 of the Society, the symposium on turbidity currents which was published in 1951, and which had more than paid for itself during the first year, has made a total profit of $1,070.25 as of December 31, 1953.

Special Publication No. 3, the symposium on finding ancient shorelines, was turned over to H. W. Menard on January 19, 1954. At that time it was partially assembled.

3. *Report of the Secretary-Treasurer (Samuel P. Ellison, Jr.).*—

BACK VOLUME SALES

(March 1, 1953 to March 1, 1954)

Back volumes of the *Journal of Paleontology*	$4,522.05
Back volumes of the *Journal of Sedimentary Petrology*	1,090.51

SPECIAL PUBLICATION SALES

(March 1, 1953 to March 1, 1954)

Turbidity Currents	$ 236.50

PRINTING AND ENGRAVING BILLS FOR 1953

Journal of Paleontology

Issue	*Banta Printing Bills* *Printing*	*Postage*	*Meriden Engraving Bills*	*Total Printing and Engraving Bills*	*S.E.P.M. Total Printing and Engraving Bills*
Number 1 (January)*	$ 2,356.41	$ 51.95	$ 813.55	$ 3,221.91	
Number 2 (March)	2,541.83	86.78	813.74	3,442.35	$3,442.35
Number 3 (May)*	2,744.35	76.17	411.84	3,232.36	
Number 4 (July)	2,068.68	64.91	582.89	2,716.48	2,716.48
Number 5 (Sept.)*	1,936.22	63.45	695.24	2,694.91	
Number 6 (November)	2,412.26	73.67	645.70	3,131.63	3,131.63
	$14,059.75	$416.93	$3,962.96	$18,439.64	$9,290.46
(1952 Totals)	($15,304.04)	($398.78)	($5,178.50)	($20,881.32)	($9,463.92)

* Odd numbers paid by Paleontological Society.

Journal of Sedimentary Petrology

Issue	*Banta Printing Bills* *Printing*	*Postage*	*Total*
Number 1 (March)	$ 989.50	$ 58.41	$1,047.91
Number 2 (June)	1,121.70	50.76	1,172.46
Number 3 (September)	936.81	35.38	972.19
Number 4 (December)	1,480.44	103.30	1,583.74
	$4,528.45	$247.85	$4,776.30
(1952 Totals)	($3,887.75)	($194.41)	($4,082.16)

MEMBERSHIP, MAILING, AND JOURNAL STATISTICS

	March 1954	*March 1953*	*March 1952*
1. S.E.P.M. Membership:			
Active Members	643	618	583
Associates	315	310	288
Honorary Members	1	1	1
Correspondents	5	5	5
TOTAL	964	934	877
2. *Journal of Paleontology* Mailing List:			
S.E.P.M. Active & Honorary Members	386	382	373
S.E.P.M. Associates	180	181	167
Subscribers	584	568	538
P.S. Members	566	573	511
TOTAL	1,716	1,704	1,589
3. *Journal of Sedimentary Petrology* Mailing List:			
S.E.P.M. Active & Honorary Members	408	385	331
S.E.P.M. Associates	193	189	170
S.E.P.M. Correspondents	5	5	5
Subscribers	596	541	489
TOTAL	1,202	1,120	995
4. Number of pages in 1953 *Journal of Paleontology*	910 (1,011, 1952)		
5. Number of plates in 1953 *Journal of Paleontology*	91 (135, 1952)		
6. Total Edition of 1953 *Journal of Paleontology*	2,100 (1,900, 1952)		
7. Number of pages in 1953 *Journal of Sedimentary Petrology*	301 (244, 1952)		
8. Total Edition of 1953 *Journal of Sedimentary Petrology*	1,400 (1,300, 1952)		
New Members from Mar. 1, 1953 to Mar. 1, 1954	45 (43, 1952–1953)		
New Associates from Mar. 1, 1953 to Mar. 1, 1954	33 (40, 1952–1953)		
Transfers to Active Membership, Mar. 1, 1953 to Mar. 1, 1954	2 (7, 1952–1953)		
Reinstatement to Active Membership, Mar. 1, 1953 to Mar. 1, 1954	1 (0, 1952–1953)		
Members and Associates dropped for non-payment of dues, 1953	37 (20, 1952)		

FINANCIAL STATEMENT FOR THE YEAR ENDED DECEMBER 31, 1953

CERTIFICATE OF INDEPENDENT PUBLIC ACCOUNTANTS

To the Council, Society of Economic Paleontologists and Mineralogists:

We have examined the balance sheet of Society of Economic Paleontologists and Mineralogists at December 31, 1953, and the related statement of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet and statement of income and surplus present fairly the financial position of Society of Economic Paleontologists and Mineralogists at December 31, 1953 and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

ARTHUR YOUNG & COMPANY

Tulsa, Oklahoma, January 27, 1954

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
BALANCE SHEET, DECEMBER 31, 1953

ASSETS	*Total*	*General Fund*	*Publication Fund*
CURRENT ASSETS:			
Cash	$10,527.81	$ 9,493.24	$1,034.57
Savings account	2,506.72	2,506.72	—
Accounts receivable	532.75	524.50	8.25
Total current assets	$13,567.28	$12,524.46	$1,042.82

PUBLICATIONS:			
Journal of Paleontology:			
Issues prior to 1953—14,792 journals at 50¢ each (2,375 complete volumes)	$ 7,396.00	$ 7,396.00	$ —
Issues 1 to 6 of 1953—1,669 journals, at cost	2,469.80	2,469.80	—
Reprints in 1948, Volume 1, 1927—758 volumes, at cost	1,661.72	1,661.72	—
Journal of Sedimentary Petrology:			
Issues prior to 1953—2,667 journals at 50¢ each (788 complete volumes)	1,333.50	1,333.50	—
Issues 1 to 4 of 1953—690 journals, at cost	538.98	538.98	—
Special publications:			
Turbidity Currents, 668 issues, at cost	571.21	—	571.21
Total publications	$13,971.21	$13,400.00	$ 571.21
FURNITURE AND FIXTURES (less reserve, $1,318.28)	$ 1.00	$ 1.00	$ —
DEFERRED CHARGES	$ 544.76	$ 544.76	$ —
	$28,084.25	$26,470.22	$1,614.03
LIABILITIES AND SURPLUS			
CURRENT LIABILITIES:			
Accounts payable	$ 2,526.68	$ 2,526.68	$ —
Amount payable to Paleontological Society	3,163.89	3,163.89	—
Accrued printer's charges	1,000.00	1,000.00	—
Total current liabilities	$ 6,690.57	$ 6,690.57	$ —
DEFERRED CREDITS:			
Subscriptions to journals (less $1,420.76 payable to Paleontological Society)	$ 4,054.39	$ 4,054.39	$ —
Membership dues for 1954 and 1955	3,912.20	3,912.20	—
Total deferred credits	$ 7,966.59	$ 7,966.59	$ —
SURPLUS (per accompanying statement)	$13,427.09	$11,813.06	$1,614.03
	$28,084.25	$26,470.22	$1,614.03

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
STATEMENT OF INCOME AND SURPLUS
YEAR ENDED DECEMBER 31, 1953

	Total	*General Fund*	*Publication Fund*
INCOME:			
Membership dues and subscriptions:			
Journal of Paleontology and Sedimentary Petrology	$ 2,510.00	$ 2,510.00	$ —
Journal of Paleontology	8,304.48	8,304.48	—
Journal of Sedimentary Petrology	4,489.22	4,489.22	—
	$15,303.70	$15,303.70	$ —
Sales of special publication—Turbidity Currents	$ 233.75	$ —	$ 233.75
Sales of back numbers:			
Journal of Paleontology, Volumes 1 to 27	$ 4,380.80	$ 4,380.80	$ —
Journal of Sedimentary Petrology	994.45	994.45	—
	$ 5,375.25	$ 5,375.25	$ —
Sales of plates	$ 440.92	$ 440.92	$ —
Advertising	$ 277.50	$ 277.50	$ —

Donation (from the American Association of Petroleum Geologists)	$ 1,000.00	$ 1,000.00	$ —
Miscellaneous	$ 259.69	$ 243.69	$ 16.00
	$22,890.81	$22,641.06	$ 249.75
Less: Proportion of 1953 income accrued to Paleontological Society	3,132.56	3,132.56	—
	$19,758.25	$19,508.50	$ 249.75
COSTS AND EXPENSES:			
Cost of printing:			
Journal of Paleontology	$ 9,568.15	$ 9,568.15	$ —
Journal of Sedimentary Petrology	4,139.88	4,139.88	—
	$13,708.03	$13,708.03	$ —
Expenses:			
Clerical salaries	$ 3,770.00	$ 3,770.00	$ —
Employee pension and death benefits plan expense	195.53	195.53	—
Office supplies	683.10	683.10	—
Postage and express	895.44	895.44	—
Office rent	1,263.50	1,263.50	—
Telephone	193.58	193.58	—
Audit fee	200.00	200.00	—
Payroll taxes	155.81	155.81	—
Miscellaneous	520.03	517.35	2.68
	$ 7,876.90	$ 7,874.31	$ 2.68
Adjustment for decrease (increase) in inventory of publications	$ (215.86)	$ (292.82)	$ 76.96
	$21,369.16	$21,289.52	$ 79.64
NET INCOME (LOSS)	(1,610.91)	(1,781.02)	170.11
SURPLUS AT DECEMBER 31, 1952	$15,038.00	$13,594.08	$1,443.92
SURPLUS AT DECEMBER 31, 1953	$13,427.09	$11,813.06	$1,614.03

4. *Report of the Research Committee (E. C. Dapples, Chairman).*—In March, 1953, the membership of the Research Committee consisted of the following personnel: J. F. Rominger, chairman, F. W. Rolshausen, Grover E. Murray, and E. C. Dapples.

Later, in May J. F. Rominger resigned from the chairmanship due to his transfer to South America, and E. C. Dapples was appointed by President Fisk to complete Rominger's term of office.

By authorization of the Council the Committee membership was expanded to nine members as follows, each new member to serve a three year term: Heinz A. Lowenstam, 1956; E. D. McKee, 1956; F. J. Pettijohn, 1956; H. E. Summerford, 1956; L. E. Workman, 1956; Bernhard Kummel, 1956; Grover E. Murray, 1955; F. W. Rolshausen, 1954, and E. C. Dapples, 1954. A wide geographic distribution of membership was selected in order to have well-defined regional representation.

The subject of the symposium which is annually presented by the Committee was selected as "Faunal facies and their lithologic associations." The plan which the symposium was to take was to have (1) an introductory paper to present the framework sediments of present day faunal distributions in areas where both sediments and fauna are variable and reasonably well understood; (2) three papers concerning ancient sediments and their organisms within restricted time spans. Each succeeding paper was to describe a more restricted time and geographic area; and (3) a closing paper of theoretical nature which was to analyze such items as the significance of populations of organisms, how to sample the

sites, and what interpretations can be drawn from the samples as gathered.

Speakers were invited and the program assembled with titles as follows:

1. "Some modern faunal and lithologic associations," by Fred B. Phleger, Scripps Institution of Oceanography.

2. "Relationships of invertebrate organisms in Pennsylvanian strata," by L. M. Cline, University of Wisconsin

3. "Relationship between fauna and lithology in the Moenkopie formation," by E. D. McKee, U. S. Geological Survey

4. "A quantitative lithofacies and biofacies study of the Florena shale (Permian) of Kansas," by John Imbrie, Columbia University

5. "Sample-population concepts in faunal-lithologic facies studies," by Robert L. Miller and Everett C. Olson, University of Chicago.

According to Article X of the By-Laws, the Research Committee is also empowered to act as an Awards Committee when so directed by the Council. This year the Committee was asked by President Fisk to initiate the awards program if the Committee so desired. The Committee scrutinized articles appearing in the 1952 issues of the *Journal of Sedimentary Petrology* and the *Journal of Paleontology*. Two articles of unquestioned outstanding quality were selected for recognition. The two are as follows:

1. "Significance of evolutionary explosions for diastrophic division of earth history," by Lloyd G. Henbest, which appeared in the May, 1952, issue of the *Journal of Paleontology;* and

2. "Turbidity currents, graded and nongraded deposits," by Philip H. Kuenen and Henry W. Menard, Jr., in the June, 1952, issue of the *Journal of Sedimentary Petrology*.

The Committee submitted its selections to President Fisk and requested that appropriate recognition be made in the form of scrolls to be presented at the joint session of the A.A.P.G.-S.E.P.M.-S.E.G.

President Fisk also asked the Research Committee for advice concerning the reprinting of *Recent Marine Sediments*. To this request the Committee made the following recommendations: (1) To reprint *Recent Marine Sediments* in its present form; (2) Generally not in favor of the Society's sponsoring a second volume patterned after *Recent Marine Sediments;* and (3) Generally in favor of the Society's sponsoring a series of volumes dealing with specific features of sediments, but to be edited by someone other than the chairman of the Research Committee.

5. *Report of the A.G.I.* (*T. H. Philpott, Director*).—A meeting of the Board of Directors of the A.G.I. was held in the Jefferson Hotel, St. Louis, Missouri, Sunday, April 11, 1954.

One of the more interesting items discussed was a change in the format of the News Letter. At the present time the News Letter has a circulation of about 1,750. It is contemplated that this will be enlarged to an edition of 17,500 and distributed to all members of the member societies. This will be accomplished by use of the Register of the National Science Foundation. It is contemplated that this will be financed by advertising.

Another matter of importance that was discussed concerned student deferments. B. F. Hake, chairman of the Committee on Government Relations, and Howard Meyerhoff, vice-chairman, discussed the Selective Service and Reserve problems. It is interesting to note that under the present interpretation of Selective Service Regulations, a student who accepts part time or summer work is subject to reclassification and call.

Five new groups were approved for affiliation with the A.G.I.: The Association of Geology Teachers, the Panhandle Geological Society (Texas), the Rocky Mountain Association of Geologists of Denver, the Indiana-Kentucky Geological Society, and the Geological Society of Washington, D. C.

The present director, Charles B. Hunt, announced his intention to return to the Geological Survey in about 18 months.

The discussion of finances, as always in the past, was an important part of the meeting. The A.A.P.G. had considered withdrawing financial support from the A.G.I. However, the A.A.P.G. is now planning to inform its membership as to the duties, responsibilities, and functions of the A.G.I. At a later date, the A.A.P.G. membership will be polled for their opinions of this matter.

I have a copy of the Constitution of the

A.G.I. as approved by the Board of Directors, November 9, 1953. There are no major changes in this Constitution and I move that it be ratified by this Business Meeting.

Motion was seconded by Stuart Levinson, and approved.

At this point, Willard D. Pye, Society representative on the Glossary of Geologic Terms Committee, asked for opinions as to whether the S.E.P.M. wished to review paleontological terms. It was decided that this was a matter for the Council's consideration and decision.

6. *Report of the Pacific Section (John Roth).*—The present membership list of the Pacific Section of the Society totals 173. This membership is concentrated largely in the two areas of Los Angeles and Bakersfield, about 125 miles to the north.

Two evening meetings held to date in Los Angeles featured the following programs:

January 13, 1954,—K. O. Emery, "Circulation of basin water of Southern California," and O. L. Bandy, "Some aspects of ecology of Foraminifera."

March 29, 1954,—W. H. Easton, "Geology, of the Illipah Quadrangle, East Central Nevada," and Paul H. Dudley, "Salient features of South Africa."

A two-day meeting and field trip, to be held jointly with the Pacific Section of the A.A.P.G. is scheduled for May 14 and 15. This program will begin with a dinner meeting in Santa Barbara on May 14, at which time the geology of a portion of the Santa Ynez Mountains will be discussed by Ben H. Page. On the following day a caravan of cars will be conducted to various vantage points in the Santa Ynez Range where the geology may be seen and fossil localities collected.

One additional Los Angeles evening meeting is planned for September and the usual half-day technical session and evening dinner meeting will be scheduled at the time of the annual joint convention in November of the Pacific Sections of the A.A.P.G., S.E.P.M., and S.E.G.

7. *Report of the Gulf Coast Section (Stuart Levinson, President).*—This is the first report of the newly organized Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists.

An initial operating fund of $335 was contributed by the Steering Committee of the Houston Geological Society, which was in charge of the joint annual meeting of the A.A.P.G.-S.E.P.M.-S.E.G. held in March, 1953, in Houston, Texas. The funds were supplied on a basis of $5.00 for each member of the Society in residence in Houston, with the provision that in the event the project to form a Gulf Coast Section of the Society failed, any remaining funds were to be turned over to the Steering Committee. It was understood that the enlistment of a substantial number of members into the organization and the election of officers would suffice to fulfill this requirement.

A steering committee was formed in June, 1953, to lay the ground work and formulate plans for the section. The steering committee was greatly assisted by an advisory committee of senior paleontologists and mineralogists of the Gulf Coast area. A charter was obtained in September, 1953, and the section then began its active organization.

As of the first of April, the section had 203 members. This corresponds with 153 S.E.P.M. members in the area. We are proud to have eight past-presidents of the Society as members of our section. It should be pointed out that our present membership is the result of sending out letters to known paleontologists and mineralogists in the area and does not nearly represent the potential membership in the area, which we soon shall strive to obtain. The section membership fee is $1.00 and membership is open to all geologists qualified to be members of the S.E.P.M., although they need not necessarily be members of the parent society. This is consistent with the qualification for membership in the Pacific Section of the Society.

To encourage section members' joining the national organizations, on each application for membership blank are boxes to be checked if the applicant desires an application form for the S.E.P.M. or the Paleontological Society. These application blanks are sent out by us with the membership card. As of April 1, 1953, 53 applications for the S.E.P.M. and 41 for the Paleontological Society have been requested.

We have recently elected our first officers. The candidates were selected by two nominating committees, each member of the

committees representing one of 13 areas of the Gulf Coast. It is believed that the interest in this young section is reflected by the fact that 82 per cent of the ballots sent out were returned, and the return envelopes were not franked.

In view of the points raised by Dr. Fisk in his Presidential Address yesterday morning, pertaining to the Society's encouragement of the formation of local sections, you will probably be interested in the expense involved in forming a section.

The report of our present treasurer, who was also treasurer of the steering committee, notes that the cost of organization, including the election of officers was $186.99. This is broken down as follows: printing, $85.90; secretarial, $45.50; franked envelopes and supplies, $55.59. Therefore, with the initial contribution of $335 and one dollar for each member, our present balance is $351.01. We are operating in the black.

We are to have an annual meeting with the Gulf Coast Association of Geological Societies. This will not be a joint meeting but rather a cooperative effort in which we will supply papers of paleontologic and mineralogic interest to round out their program. Our first meeting with them will be in November of this year and our program committee is quite active.

We will also present papers in conjunction with the local geological societies and will assist them in planning field trips. We are not contemplating any local meetings of our own at this time.

There are a number of our section committees actively working, one of the more important being our constitution committee. We will have a copy of our proposed constitution in the hands of the section membership by September 1 of this year.

We are currently planning the appointment of committees to be engaged in short-term projects—projects needed to assist the paleontologist and mineralogist in his work and to improve the status of paleontologists and mineralogists in the Gulf Coast area. We hope that you will see some of the results of our section's activities during the forthcoming year.

8. *Report on the Journal of Paleontology Index* (*Hans Thalmann*).—In November, 1946, at the annual meeting of the Geological Society of America in Chicago, J. Marvin Weller persuaded the writer to undertake the compilation of the *Index* of all described and cited fossils contained in the first twenty volumes (1927 to 1946) of our *Journal of Paleontology*.

Work was started during 1947, and continued during the writer's spare time (mostly on evenings and Saturdays and Sundays) during 1948 and 1949 in Caracas, Venezuela, ably assisted by Wolf Maync. While the writer took over the first ten volumes, Maync devoted his spare time to volumes 11 to 20, inclusive.

During 1949, word was received from Marvin Weller that the Society had no money available for printing this *Index*, once completed. For this reason Maync and the writer stopped this time-consuming task.

When the writer left Caracas in January, 1950, his portion of the *Index* (volumes 1 to 6, inclusive, completely card-indexed) was packed for shipment in a heavy cardboard box and sent by boat directly to Los Angeles. Maync's portion (volumes 11 to 17, inclusive, completely indexed then), packed in a wooden box, arrived in Los Angeles two weeks after Thalmann's shipment. The cardboard box arrived crushed and oil-stained, and the cards could not be used, while the wooden box arrived intact. During 1952, Thalmann received at Stanford volumes 18 to 20, inclusive, from Maync.

It was then decided, encouraged by Grover Murray, to continue the indexing, and to include also volumes 21 to 25 (1947 to 1951). Joseph J. Graham, at Stanford, took over the first seven volumes and had them indexed by Mr. and Mrs. Don Bryant. During 1953, their cards were checked by Graham and Clifford C. Church.

The present status of this general index as of April 1, 1954, is as follows: volumes 1 to 7, indexed by Mrs. Bryant (complete, and checked by Graham and Church); volumes 8 to 10, in preparation by the writer; volumes 11 to 20, completely indexed by Maync and checked by Thalmann; volumes 21 to 25, still to be indexed.

All indexing is done on 3×5 cards, and after completion of the work these cards will have to be arranged alphabetically and bundled together to be submitted as a "manuscript in card-form" to the printer. This

method of handling the *Index* was suggested by Marvin Weller after consultation with Banta Publishing Company officials.

On many occasions, Thalmann tried to interest students in helping to bring this task to a successful end, but such efforts were in vain, and all students deserted the work within five to 12 days.

Owing to more pressing work and duties, the writer can spend only an occasional evening per week for this task. However, if 15 enthusiastic paleontologists could be found, each of whom would be willing to take over the indexing of two of the remaining 30 numbers, of volumes 21 to 25, inclusive, the work could be finished within, let us say, two months.

The only expenses involved in preparing this material for the printer will be about $60 to $65 for the thousands of 3×5 index cards, and the payment of about $150 to $200 salary for an assistant for alphabetizing and preparing the cards for print.

9. *Report on History of S.E.P.M.* (*Marcus A. Hanna, Co-Editor*).—This paper is progressing slowly and considerable work remains to be done. I am now going over what minutes are available from the early officers. The Headquarters files in Tulsa were examined in November and a part of the minutes sent to me in Houston. I am going over these. Merle Israelsky's files are being shipped to me now. I will do the preliminary work on the files I now have, then jointly work with Henry V. Howe, the co-author, for final preparation. At a later stage much correspondence will be necessary to fill in the many gaps in the presently available information. My only reason for not working with the co-author in early stages is that Baton Rouge and Houston are 300 miles apart. You may rest assured that Dr. Howe will be a major co-author before the history is finished.

10. *Report of the Advisory Committee on Radioactive Mineral Exploration* (*Clifford C. Church, S.E.P.M. Representative*).—Since the appointment of your representative, the Advisory Committee on Radioactive Mineral Exploration has met in Denver, Colorado, May 5 and November 17, 1953. Ten members and alternates were present at the first meeting, and 11 members and alternates with two visitors at the second meeting. The full membership is 15 members.

It was decided in the May meeting that two meetings per year would be sufficient to conduct committee business. The chairman, F. H. Lahee, pointed out the willingness of the Atomic Energy Commission to cooperate with the Committee in its efforts to interest the petroleum industry in the search for radioactive minerals. The areas known to be important possible sources for radioactive minerals in the western United States were listed as follows: Uinta Basin, Utah; Western Wyoming; Big Horn Basin, Wyoming; Little Colorado River Drainage Area, Arizona; Mojave and Colorado Desert Areas, Southern California and Arizona.

In the areas mentioned, it was stated that ten major oil companies now have one or more of their seismic crews supplied with Geiger Counters and at least 40 seismic crews have been supplied with Counters within the last one and a half years. The most practical method for examining the shot holes was discussed and it was decided that a small, down-the-hole probe offered good possibilities for quick and accurate location of ore, but an examination by a Geiger Counter of the cuttings brought to the surface would suffice to determine the presence of radioactive minerals.

The possibilities of Gamma Ray Logs were discussed as recording indications of radioactive minerals in deeper wells drilled for oil. Reference was also made to the airborne radiometric surveys being made by the United States Atomic Energy Commission. Maps showing areas of high radioactivity are published each month and these are available about the fifteenth of each month for the areas flown during the preceding month. The United States Geological Survey also carries on a similar areas survey.

In connection with the conflict between uranium mining locations and oil and gas leases, Royal S. Foote of the Atomic Energy Commission wrote that, "An arrangement is now in effect whereby uranium miners who have staked ground on pre-existing oil and gas leases will, by execution of a lease with the A.E.C., have the right to produce and sell uranium ore and be certified for the A.E.C. bonus payments."

Circular No. 3 of the Advisory Commit-

tee came out following the meeting of May 5. It is, in part, a summary of results of that meeting with some answers to questions brought up at the meeting as to methods of exploitation, land ownership, etc. This and other circulars are available, through the chairman, to anyone interested. Four have been issued to date.

At the November meeting, Mr. Foote of the A.E.C., New York, and M. E. Denson, Geophysical Department, A.E.C., Denver, were present. Mr. Foote described the nature and scope of their search for radioactive minerals. He described four instruments using a probe for hole logging. Three (A, B, and D) constructed under the supervision of the A.E.C., and one (C) by the U.S.G.S. Instruments B, C, and D were exhibited in the conference room and their uses described. The advisability of using down-the-hole probes or surface examination of shot hole cuttings was again discussed and the probe was suggested as the best means of accurately locating the ore bearing beds.

On the subject of new discoveries since the May meeting, two new minable occurrences have been found as a result of logging seismic shot holes, and ten operating mines have been discovered as a result of airborne radiometric surveys. This does not include similar surveys conducted by private concerns. The U.S.G.S. has made three discoveries by air reconnaissance. These are not yet in operation.

The most important discovery is that of Mr. Steen near Moab in southeast Utah. It was found by core drilling back from the canyon edge where radioactive material was exposed. This one body is rated to be worth 50 million dollars or more.

The over-all importance of the western states production of uranium may be better understood from a statement from an official of the A.E.C. as follows, "Production from deposit of this category . . . now ranks the United States in second place among the world's uranium producing countries."

The continued importance of uranium mining is assured from the fact that the commission has extended the basic price schedules and incentive payments until April, 1962, and the initial production bonus is guaranteed until February 28, 1957.

Following the last meeting, on November 17, a memorandum on functions, organization, and rules of the Advisory Committee appeared under date of February 12, 1954. In this the two meetings per year were fixed and the tenure of service of committee members set at three years. Five appointments will be made at each annual meeting to replace the five expirations. The next meeting of the Committee will be in Denver on May 20, 1954.

This is a brief résumé of some of the more important actions of the Committee and does not attempt to cover all issues.

11. *Presidential Summary* (*Harold N. Fisk*).—Perhaps the most important event this year with regard to activities of the Society was the establishment of the Gulf Coast Section. Over 200 paleontologists and mineralogists in the Gulf Coast region make up this new Section of the Society. Officers have been chosen and a program is being formulated which should result in many worthwhile contributions to geology.

This year the Council acted to extend the activities and increase the membership of the Research Committee. An amendment to the By-Laws, Article X, was formulated by a committee headed by M. B. Stephenson and was approved by the Society membership in a mailed ballot. The Research Committee will now consist of approximately 14 members, selected to represent paleontologists and mineralogists from various sections of the country, with junior and senior members from each section. It will continue to advise on research activities which may concern the Society, to develop symposia for annual meetings, and is now charged with the responsibility of selecting recipients for various Society awards.

To ensure well-informed leadership, another amendment to the By-Laws was drafted by a committee headed by W. C. Krumbein. This amendment will be submitted at this Business Meeting for consideration. It provides that nominees for president shall be selected from men who have held previous elective posts in the Society, or have served as editor, or as Chairman of the Research Committee. Another amendment to the By-Laws has been prepared for submittal to this meeting, which states that the vice-president will be responsible for arrangements for the annual convention program.

As in preceding years, the Society incurred a deficit, this year $2194, and the A.A.P.G. Executive Committee has agreed for the Association to assume it. The budget that has been approved by the Council is such that this year's deficit will be approximately $4000. It is obvious that the increasing annual deficit can not continue if we expect to obtain continuing support of the A.A.P.G. This annual deficit is brought about largely by increased publication costs. To meet it we are faced with the problem of either decreasing the size and quality of the *Journals* or raising dues and subscription prices. Certainly we can not expect the A.A.P.G. to assume this deficit, and at the same time increase the scope of our publications, which is required by the increasing membership. It is hoped that the matter of making the S.E.P.M. as self-sufficient as possible will be largely resolved with a decision to increase Society dues. The matter has been discussed with the Paleontological Society whose Council has agreed to raise its dues in accordance with S.E.P.M. changes to a maximum increase of $2.00 per year. A motion concerning this increase in dues will be presented in the form of an amendment to the By-Laws for consideration at this meeting.

As indicated in the reports of the editors and the Research Committee chairman, the Society has this year released no special publication, but the symposium, *Finding Ancient Shoreline*, is in final stages of editing, according to H. W. Menard, Jr. The question of reprinting or revising the A.A.P.G. Special Publication, *Recent Marine Sediments*, was submitted to the Research Committee, and their findings were to the effect that the paper should be reprinted, but not revised. Steps will be taken to do this. The Committee also recommended that the Society sponsor additional volumes on Recent sediments.

It was moved by H. V. Howe, seconded by M. A. Hanna, and approved that the foregoing reports be accepted.

After discussion by Samuel P. Ellison, Ralph Grim, and Grover Murray of the ever-increasing costs of publication and the growing annual deficit of the Society, in spite of the increase in membership and nonmember subscribers, it was moved by Grover Murray that By-Laws Article I, Section 2, be changed to read as follows, becoming effective on January 1, 1955.

"2. The annual dues of members and associates of the Society who desire only the *Journal of Paleontology* shall be eight dollars ($8.00). The annual dues of members and associates who desire only the *Journal of Sedimentary Petrology* shall be five dollars ($5.00). Members and associates may receive both *Journals* by the payment of thirteen dollars ($13.00). Members of the Society, who are also members of the Paleontological Society and receive the *Journal of Paleontology* through the latter Society, may retain membership in the Society of Economic Paleontologists and Mineralogists by the payment of one dollar ($1.00) per year dues. The annual dues are payable in advance on the first day of each calendar year. A bill shall be mailed to each member and associate before September 1 of each year, stating the amount of annual dues and the penalty and conditions for default of payment. Members and associates who shall fail to pay their annual dues by January 1 shall not receive further copies of either *Journal*, nor shall they be privileged to buy Society publications at special discount made to the membership, until such arrears are met."

The motion was seconded and after much discussion it was approved, thereby increasing dues $2.00 per year for the *Journal of Paleontology* and $1.00 per year including the *Journal of Sedimentary Petrology*, effective January 1, 1955.

It was then moved by Grover Murray that the members of the S.E.P.M. approve the action of the Council in increasing subscription rates of the *Journal of Paleontology* from $10.00 to $15.00 per annum and those of the *Journal of Sedimentary Petrology* from $5.00 to $6.00 per anum beginning with January 1, 1955. Motion was seconded, discussed, and approved.

Grover Murray then moved that the price of back numbers of the *Journal of Paleontology*, Volumes 2–28, inclusive, be increased from $1.50 to $1.75 per number to members and from $2.00 to $3.00 to non-members, effective immediately,—that a discount be allowed to non-members as follows: 10 per cent on orders totalling $25 to $49, inclusive;

20 per cent on orders totalling $50 to $99, inclusive; and 25 per cent on orders totalling $100 and over,—and that the price of back numbers of the *Journal of Sedimentary Petrology* be increased from $1.35 to $1.50 per number for members and from $1.75 to $2.00 per number for non-members, effective immediately, but that no discount be allowed on orders for back numbers of this *Journal*, because of their scarcity. This motion was seconded and approved.

H. A. Ireland reminded the group of the favorable results from the work of Hollis Hedberg's membership committee a few years ago and recommended that a membership drive be made. He was advised that the incoming president plans to appoint a membership committee for this purpose.

M. A. Hanna reported that he had been a member of a committee appointed to formulate an amendment to the By-Laws regarding eligibility for nomination to the presidency. He read the following letter from W. C. Krumbein, chairman, to H. N. Fisk, president,

". . . The committee wishes to go on record as emphasizing that this amendment does not imply in any way that any past president, who did not fulfill the requirements of the proposal, was in any way lax in his duties. There is thus no reflection whatever on past officers; in fact, in a large sense past officers who themselves did not fill these requirements were responsible for this proposed amendment.

"The committee also realizes that this proposed amendment very definitely spells out who may become president of the S.E.P.M. At worst, however, the amendment would require a delay of one year in electing a man whom we may particularly want as president, yet who had not satisfied the requirements earlier.

"I believe that the greatest advantage of the amendment is that it will serve to remind officers and nominating committees of men who had been selected for active positions in the Society, and yet who may be overlooked in naming nominees. This is strikingly brought out by the attached list of names of men who are now eligible for nomination to the presidency. It is evident that we have a fine choice of men, any one of whom would make a fine president. I should mention in passing that my list may not be complete, but even as it is, it shows the possibilities.

"An additional consideration in favor of the amendment, in my own mind at least, is the fact that we are a Society which of necessity throws a heavy burden on the president from the very day when he first assumes office. It is in some ways unfair to the candidate suddenly to weight him with this responsibility if he has not been prepared by some active participation in the Society's problems.

"The committee would prefer that this letter be part of any transmittal of the proposed amendment to the Executive Committee of the A.A.P.G., as well as to our own S.E.P.M. business meeting, if the Council proposes to submit it."

Dr. Hanna then moved that Article III, Section 4, of the By-Laws be enacted herewith: Article III, Section 4.

"Nominees for the office of president shall be active members in good standing, who shall have served (or may be serving concurrently at the time of nomination) as vice-president, secretary-treasurer, chairman of the Research Committee, or editor of one of the society's official publications."

Motion was seconded and after much discussion, was approved by the members present.

W. Thomas Rothwell, Jr., moved that the following By-Laws Article III, Section 5, be enacted herewith:

ARTICLE III, SECTION 5.

"The vice-president shall be the officer of the Council responsible for arrangements for the annual meeting, including selection of program chairmen, and shall keep in close contact with the Research Committee and others concerning technical papers and symposia to be presented."

Motion was seconded by Dana Russell and approved.

William Easton moved that the motion concerning increase in membership dues be re-opened. Motion was seconded by Stanley Wissler. During discussion, Mr. Easton stated that he felt the Paleontological Society's attitude toward this increase had not been clearly presented and that he would like to hear a statement from a P. S. repre-

sentative. Dr. Fisk then read the letter from President Ladd stating that if the S.E.P.M. felt it was necessary to increase its dues to meet expenses, the Paleontological Society would approve a similar increase in its dues, to a maximum of $2.00 per member. The motion to re-open the motion concerning increase in membership dues was then opposed by the members present.

The meeting was then turned over to incoming President Hans Thalmann.

It was moved by Harold Fisk, seconded by Dana Russell, and approved that the following resolutions be adopted:

BE IT RESOLVED THAT in behalf of the Society we extend an expression of our sincere thanks to the following:

TO H. A. IRELAND, chairman, and the members of the S.E.P.M. Technical Program Committee, and to the speakers, for the high quality of the papers presented on the 1954 program;

TO E. C. DAPPLES, chairman of the Research Committee, and the members of his committee, for the excellent research symposium for the 1954 annual meeting;

TO R. J. LEBLANC, for planning and arranging the very fine symposium on "Regional aspects of carbonate deposition";

TO GRAHAM B. MOODY, general chairman of the convention, Noel H. Stearn, general vice-chairman, Norman S. Hinchey, vice-chairman for the S.E.P.M., and to the chairmen and members of all the convention sub-committees for capable leadership and assistance in organizing and holding the St. Louis meeting;

TO THE JEFFERSON HOTEL, for providing excellent convention headquarters facilities;

AND TO THE CITY OF ST. LOUIS, for the use of the Kiel Auditorium and for full cooperation at all times.

It was moved by M. A. Hanna that a vote of thanks be given to the outgoing officers for their untiring service to the Society during the past year and for their many accomplishments. Motion was seconded and unanimously approved.

The business session adjourned at 6:30 P.M., Wednesday, April 14, 1954.

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

A DIVISION OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Box 979, Tulsa, Oklahoma

CONSTITUTION

ARTICLE I. NAME

The Society shall be known as the Society of Economic Paleontologists and Mineralogists.

ARTICLE II. OBJECT

The object of the Society shall be to promote the science of stratigraphy through research in paleontology and sedimentary petrology, especially as these relate to development of knowledge of the geology of petroleum.

ARTICLE III. MEMBERSHIP

1. The Society shall be composed of active members, associate members, honorary members, correspondents, and patrons.

2. Active members shall be persons engaged in paleontologic, petrographic, or stratigraphic studies as applied to the geology of petroleum and who have been duly elected members or associate members in the American Association of Petroleum Geologists.

Active members alone shall be known as members.

3. Associate members shall be known as associates. Any person engaged in paleontologic, petrologic, or stratigraphic studies that have application to the geology of petroleum is eligible for associate membership. Associates shall enjoy all the privileges of membership in the Society, save that they shall not hold office, sign applications for membership, or vote.

4. Honorary members shall be persons of distinguished achievement whose contributions to paleontology, petrology, and stratigraphy have an application to the geology of petroleum.

5. Correspondents shall be persons not

resident in North America who have made distinctive contributions to paleontology, petrology, and stratigraphy that have application to the geology of petroleum.

6. Patrons shall be persons who have bestowed important favors on the Society.

ARTICLE IV. OFFICERS

1. Executive authority of the Society is vested in a council consisting of five members, duly elected officers, as follows: president, vice-president, secretary-treasurer, and the two most recently retired past-presidents.

2. The president shall discharge the usual duties of a presiding officer at all meetings of the Society and council.

3. The vice-president shall assume the duties of the president in case of his absence.

In the event of the absence from the meetings of both president and vice-president the duties of presiding officer shall fall upon one of the other members of the council in the following order: most recent past-president, second most recent past-president, secretary-treasurer.

4. The secretary-treasurer shall keep record of the proceedings of the Society, and a complete list of the membership. He shall attend to the preparation and mailing of notices and other materials required in the business of the Society. The secretary-treasurer shall have custody of all funds of the Society, and shall keep a detailed account of receipts and disbursements.

5. The council shall consider all nominations for membership and pass on the qualifications of the applicants; shall have control and management of the affairs and funds of the Society; shall determine the manner of publication and pass on the material presented for publication; and shall designate the place of the annual meeting. It is empowered to establish a business headquarters for the Society and to employ such persons as are needed to conduct the business of the Society.

6. Elections shall be held annually to select a president, vice-president, and secretary-treasurer.

ARTICLE V. MEETINGS

1. The Society shall hold at least one stated meeting a year, which shall be designated as the annual meeting. The time and place of the annual meeting shall be designated by the council, but in general, it shall be held in connection with the annual meeting of the American Association of Petroleum Geologists.

2. The annual meeting shall be devoted to the reading and discussion of scientific papers, to the transaction of Society business, and other appropriate functions.

3. The program for the annual meeting shall be arranged by the council, or under its direction.

ARTICLE VI. SECTIONS

1. Local sections of the Society may be established according to provisions of the by-laws.

ARTICLE VII. AMENDMENTS

The constitution may be amended by a two-thirds vote of returned mail ballots received by the secretary-treasurer sixty days after proposal of amendments with provision for vote is mailed to the membership; provided that the proposed amendment has been signed by at least twenty members, and provided further that the proposed amendment must first have the approval of the council, and the executive committee of the American Association of Petroleum Geologists.

BY-LAWS

ARTICLE I. DUES

1. The fiscal year of the Society shall correspond with the calendar year.

2. The annual dues of members and associates of the Society who desire only the JOURNAL OF PALEONTOLOGY shall be eight dollars ($8.00). The annual dues of members and associates who desire only the JOURNAL OF SEDIMENTARY PETROLOGY shall be five dollars ($5.00). Members and associates may receive both Journals by the payment of thirteen dollars ($13.00). Members of the Society, who are also members of the Paleontological Society and receive the JOURNAL OF PALEONTOLOGY through the latter society, may retain membership in the Society of Economic Paleontologists and Mineralogists by the payment of one dollar

($1.00) per year dues. The annual dues are payable in advance on the first day of each calendar year. A bill shall be mailed to each member and associate before September 1 of each year, stating the amount of annual dues and the penalty and conditions for default of payment. Members and associates who shall fail to pay their annual dues by January 1 shall not receive further copies of either JOURNAL, nor shall they be privileged to buy Society publications at special discounts made to the membership, until such arrears are met.

3. Honorary members, correspondents, and patrons may be nominated by a vote of four members of the Council and such nomination shall be submitted to the members by mail ballot. Provided eighty per cent or more of the returned ballots are favorable, the nominee shall be declared elected. Honorary members, correspondents, and patrons shall not be required to pay annual dues.

ARTICLE II. DUTIES AND PRIVILEGES OF MEMBERS

1. Members and associate members dropped for non-payment of dues may apply to the council for reinstatement, and, provided settlement is made of any outstanding indebtedness for publications and other charges approved by the council, may be reinstated by vote of four members of the council.

2. Members shall be eligible to receive publications of the Society at special subscription rates as authorized by the council or as provided in these by-laws.

3. The council is authorized to transmit without charge such publications as it may direct to honorary members, correspondents, and patrons.

4. Only active members shall have the right to vote in electing officers and in transacting the business of the Society.

ARTICLE III. OFFICERS

1. Nominations for officers shall be made in the following manner. Prior to September 1 of each year, the president shall designate two nominating committees, instructing each committee to submit nominations for president, vice-president, and secretary-treasurer, these nominations to be in the secretary's hands before September 15. If desired, the same person may be nominated by the two committees for the office of secretary-treasurer, but nominations for president and vice-president shall not include the name of the same person on the two slates. The nominations of the first committee to file its report will have precedence in case of overlapping nominations and the other committee shall then be requested to change its nomination.

2. Ballots containing the nominations for officers, alphabetically arranged under each office, shall be prepared by the secretary-treasurer and mailed to each member of the Society on or before October 1. Neither the ballot nor the enclosing envelope need contain the name of the voting member, but an outer envelope that contains the sealed ballot must bear the name of the voting member. The returned ballots received by the secretary-treasurer on or before December 1 shall be counted by him, and if requested, shall be submitted to recount by the council. A plurality of the votes received for any office constitutes election.

3. If, after his election by the regular ballot, the president shall not be able to discharge the duties of his office, because of death or resignation, the duly elected vice-president shall then assume the duties and title of president with all of the authority vested in him by the Constitution. In the event the vice-president shall not be able to assume said duties, then the succession shall be in the following order: Most recent past-president, second most recent past-president, secretary-treasurer. If none of the above mentioned members of the Council shall be able to assume the office of the president, then a special election shall be held in which at least two qualified members, nominated by the Council, shall be voted upon by the membership by means of a special mailed ballot. Any vacancies in the normally constituted Council caused by such succession may be filled with a temporary appointment by the Council.

4. Nominees for the office of president shall be active members in good standing, who shall have served (or may be serving concurrently at the time of nomination) as vice-president, secretary-treasurer, chairman of the Research Committee, or editor

of one of the Society's official publications.

5. The vice-president shall be the officer of the Council responsible for arrangements for the annual meeting, including selection of program chairmen, and shall keep in close contact with the Research Committee and others concerning technical papers and symposia to be presented.

ARTICLE IV. PUBLICATIONS

1. The council is authorized and directed to make such arrangements for editorial preparation of manuscripts, publication, distribution, general business management of publications, and all other proper matters connected with efficient handling of publications of the Society not provided for in the constitution as it shall deem desirable in the Society's interest. This includes designation of an editor or editors, who shall serve at the pleasure of the council in the formulation of publication policies, including the making of contracts for printing, and engraving, entering into agreements with other scientific societies for joint publication, and acceptance of advertising at determined rates. The council shall supply the editor or editors with a publication budget at the annual meeting of the Society. This budget may be expanded or contracted at later date by vote of the council. In this matter, and in other matters affecting publication policy, the editor or editors of the JOURNAL OF PALEONTOLOGY and the JOURNAL OF SEDIMENTARY PETROLOGY shall be members ex-officio of the Council. Each shall have a vote in all matters pertaining to the Society's publications except in regard to the appointment, or removal of the editors. In the event there are co-editors of either JOURNAL, these co-editors shall have one-half vote each.

2. The JOURNAL OF PALEONTOLOGY and the JOURNAL OF SEDIMENTARY PETROLOGY are designated as official publications of the Society. The council is not authorized to initiate and publish other periodicals.

3. A publication fund may be established consisting of an assignment of a portion of dues as designated by the council, and such donations as are specifically made for that purpose. The council is authorized to provide special publications from this fund as may be deemed desirable, and to fix terms for sale or other distribution of these publications.

ARTICLE V. FINANCIAL METHODS

1. No financial obligations shall be contracted without express sanction of the Society or council, but all ordinary incidental running expenses have sanction without special action.

2. Statements of accounts charged to the Society, other than miscellaneous running expenses, shall be approved by the president before the secretary-treasurer pays the amount out of funds of the Society not otherwise appropriated, and the receipted bill shall be held as the secretary-treasurer's voucher.

3. The secretary-treasurer shall have charge of the financial affairs of the Society and shall annually submit reports as secretary-treasurer covering the fiscal year. He shall receive all funds of the Society, and, under the direction of the council, shall disburse all funds of the Society. He shall cause an audit to be prepared annually by a public accountant at the expense of the Society. He shall give a bond, and shall cause to be bonded all employees to whom authority may be delegated to handle Society funds. The amount of such bonds shall be set by the council and the expense shall be borne by the Society. The funds of the Society shall be disbursed by check as authorized by the council.

ARTICLE VI. BUSINESS REPRESENTATIVES

1. The president and the secretary-treasurer of the society shall act as business representatives of the Society in the business committee of the American Association of Petroleum Geologists. These representatives shall conduct such business with the executive committee of the Association as is of mutual interest to the Society and the Association in the interims between the annual meetings of the Society and the Association. Approval of the action of these representatives on the part of the Society during any year is reserved to the council in session at the annual meeting at the close of that year. Questions remaining unsettled between the representatives of the Society and the executive committee of the Association shall be considered in a joint meet-

ing of the Council of the Society or its authorized representatives and the executive committee of the Association at the annual meeting of the Association at the close of the interim period during which such questions have arisen.

ARTICLE VII. SECTIONS

1. The establishment of local sections of the Society may be authorized by unanimous vote of the council approving a petition for such establishment signed by ten members of the Society. Such local sections may elect officers, conduct meetings, and engage in other scientific activities, but shall not be entitled to special representation in general Society affairs.

2. The council is authorized and directed to withdraw the charter of any established local section if there is evidence that it has become inactive.

ARTICLE VIII. AMENDMENTS

1. The by-laws may be amended at any annual business meeting by two-thirds vote of the members present, or by mail ballot sent to the members, in which case two-thirds of the returned ballots received in sixty days after mailing must approve the amendment in order to make it effective. Any proposed changes to the by-laws must first have the approval of the council.

ARTICLE IX. DIRECTORS OF AMERICAN GEOLOGICAL INSTITUTE

1. The president of the Society shall become a director of the American Geological Institute at the close of that annual meeting of said Institute which follows his term as president. He shall represent the Society on said Institute and shall serve in that capacity for two years, a year being construed as the period extending from the close of one annual meeting of said Institute to the close of the next in accordance with Article IV, Number 2, of the Articles of Organization of the American Geological Institute.

2. In the event of a vacancy by resignation, death, or other causes among the two directors who represent the Society on said Institute, the president of the Society shall nominate a director from the ranks of associate or active members of the Society, and this director shall complete the unexpired term.

ARTICLE X. RESEARCH COMMITTEE

1. The objectives of the Research Committee shall be to foster and encourage research; to advise the Society and Council on research activities which may concern the Society, or which may be recommended or initiated under its sponsorship; to develop a symposium for the annual meeting if so requested; to select recipients for Society awards; and to deal with any other matters referred to it from time to time by the president or the Council.

2. The activities of the Committee shall be directed by a chairman and vice-chairman, to be appointed by the president from the members of the Committee. In the event either of these offices is vacated for any reason, the president shall appoint a qualified replacement of the the unexpired term.

3. Membership of the Committee shall be appointed by the president from members and associates of the Society. The Committee shall consist of fourteen members, but this total may be changed at the discretion of the Council. Two committee members, preferably one paleontologist and one mineralogist, shall be chosen from each of several geographic regions to be selected by the Council. In addition, advisory members may be appointed from foreign areas. The terms of appointment of members and advisory members shall be for three years. Appointments shall be staggered, with the junior member from any region serving at least one year with the senior member from that region. If vacancies develop on the Committee the president shall make suitable appointments for the unexpired term.

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

P.O. Box 979, Tulsa 1, Oklahoma

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